L Number	Hits	Search Text	DB	Time stamp
1	40517	MRAM (magnetic near4 memory)	USPAT; US-PGPUB; EPO; JPO; DERWENT; IBM_TDB	2003/09/02 13:45
2	3376	(MRAM (magnetic near4 memory)) and ((magnet$2 ferromagnet$2) adj2 layer)	USPAT; US-PGPUB; EPO; JPO; DERWENT; IBM_TDB	2003/09/02 13:46
3	996	magnet$2 near3 tunnel$3 near3 junction	USPAT; US-PGPUB; EPO; JPO; DERWENT; IBM_TDB	2003/09/02 13:47
4	517	((MRAM (magnetic near4 memory)) and ((magnet$2 ferromagnet$2) adj2 layer)) and (magnet$2 near3 tunnel$3 near3 junction)	USPAT; US-PGPUB; EPO; JPO; DERWENT; IBM_TDB	2003/09/02 13:47
5	10	(((MRAM (magnetic near4 memory)) and ((magnet$2 ferromagnet$2) adj2 layer)) and (magnet$2 near3 tunnel$3 near3 junction)) and ((magnet$2 near3 tunnel$3 near3 junction) with source) and ((magnet$2 near3 tunnel$3 near3 junction) with gate)	USPAT; US-PGPUB; EPO; JPO; DERWENT; IBM_TDB	2003/09/02 14:02
8	0	(MRAM (magnetic near4 memory)) and ((magnet$2 adj2 tunnel$3) near3 source) and ((magnet$2 adj2 tunnel$3) near3 gate)	USPAT; US-PGPUB; EPO; JPO; DERWENT; IBM_TDB	2003/09/02 14:03
6	14	(MRAM (magnetic near4 memory)) and ((magnet$2 near3 tunnel$3 near3 junction) with source) and ((magnet$2 near3 tunnel$3 near3 junction) with gate)	USPAT; US-PGPUB; EPO; JPO; DERWENT; IBM_TDB	2003/09/02 14:03
7	1	(MRAM (magnetic near4 memory)) and ((magnet$2 near3 tunnel$3 near3 junction) near3 source) and ((magnet$2 near3 tunnel$3 near3 junction) near3 gate)	USPAT; US-PGPUB; EPO; JPO; DERWENT; IBM_TDB	2003/09/02 14:17
13	0	(MRAM (magnetic near4 memory)) and ((junction adj3 end) near3 gate) and ((junction adj3 end) near3 source)	USPAT; US-PGPUB; EPO; JPO; DERWENT; IBM_TDB	2003/09/02 14:23

File View Edit Tools Window Help

- Drafts
- Pending
- Active
  - L1: (40517) MRAM (magnetic near4 memory)
  - L2: (3376) L1 and ((magnet$2 ferromagnet$2) adj2 layer)
  - L3: (996) magnet$2 near3 tunnel$3 near3 junction
  - L4: (517) L2 and L3
  - L5: (10) L4 and ((magnet$2 near3 tunnel$3 near3 junction) with source) and ((mag
  - L8: (0) L1 and ((magnet$2 adj2 tunnel$3) near3 source) and ((magnet$2 adj2 tunne
  - L6: (14) L1 and ((magnet$2 near3 tunnel$3 near3 junction) with source) and ((mag
  - L7: (1) L1 and ((magnet$2 near3 tunnel$3 near3 junction) near3 source) and ((mag
  - L13: (0) L1 and ((junction adj3 end) near3 gate) and ((junction adj3 end) near3
- Failed
- Saved
- Favorites
- Tagged (2)
- UDC
- Queue
- Trash

Search | List | Browse | Queue | Clear

DBs: USPAT; US-PGPUB; EPO; JPO; DERWENT; IBM_TDB

Plurals

Default operator: OR

Highlight all hit terms initially

L1 and ((junction adj3 end) near3 gate) and ((junction adj3 end) near3 source)

BRS form | IS&R form | Image | Text | HTML

	U	I	Document ID	Issue Date	Pages	Title	Current OR	Current XRef	Retrieval C	Inventor	S	C	P

Hits | Details | HTML

Ready

NUM

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] Drawing showing the magnetic memory cell which consists of a magnetic-substance tunnel junction element concerning the 1st operation gestalt of this invention, and an MOS transistor
[Drawing 2] Drawing showing the spin dependency of the density of states of the magnetic substance
[Drawing 3] Drawing showing the density of states of a super-thin film
[Drawing 4] Drawing showing the wave number vector of the electron which tunnels an insulator layer
[Drawing 5] The cross section showing a magnetic-substance electrode
[Drawing 6] The cross section showing other magnetic-substance electrodes
[Drawing 7] The cross section showing a magnetic-substance tunnel junction element
[Drawing 8] Drawing showing the measurement result of the magnetoresistance effect of the magnetic-substance tunnel junction element of drawing 7
[Drawing 9] The cross section showing other magnetic-substance tunnel junction elements
[Drawing 10] Drawing showing the magnetic memory cell concerning the 2nd operation gestalt of this invention
[Drawing 11] Drawing showing the dependency of the collector to base voltage of the emitter current at the time of using a Nb dope n type STO layer as an emitter layer
[Drawing 12] Drawing showing the magnetic head concerning the 3rd operation gestalt of this invention

[Drawing 13] Drawing showing the magnetic head concerning the 4th operation gestalt of this invention
[Drawing 14] The cross section showing the magnetic-substance element concerning the 5th operation gestalt of this invention
[Drawing 15] Drawing showing the emitter voltage dependency of MR ratio
[Drawing 16] Drawing showing the thickness dependency of Fe film in the emitter of MR ratio
[Drawing 17] The cross section showing the magnetic-substance element concerning the 6th operation gestalt of this invention
[Drawing 18] The cross section showing the magnetic-substance element concerning the 7th operation gestalt of this invention
[Drawing 19] The cross section showing the modification of the magnetic-substance element of drawing 7
[Drawing 20] The cross section showing the magnetic-substance element concerning the operation gestalt of the octavus of this invention
[Drawing 21] The cross section showing the magnetic-substance element concerning the 9th operation gestalt of this invention
[Drawing 22] The cross section showing the magnetic-substance element concerning the 10th operation gestalt of this invention
[Drawing 23] The cross section showing the magnetic-substance element concerning the 11th operation gestalt of this invention
[Drawing 24] The cross section showing the magnetic-substance element concerning the 12th operation

gestalt of this invention
[Drawing 25] The cross section showing the magnetic-substance element concerning the 13th operation gestalt of this invention
[Drawing 26] Drawing showing a conventional tunnel pouring type hot electron transistor
[Drawing 27] Drawing showing a conventional Schottky pouring type hot electron transistor
[Drawing 28] Drawing showing the magnetic memory cell which consists of a conventional magnetic-substance tunnel junction element and a conventional MOS transistor
[Description of Notations]
1 -- Magnetic-substance tunnel junction element (a memory cell main part, magnetic-head main part)
2 -- MOS transistor
3 -- Comparison resistance (2nd resistance)
4 -- Gate resistance (1st resistance)
5 -- Si substrate
6 -- Backup film
7 -- Barrier film
8 -- Magnetic-substance super-thin film
9 -- Hot electron transistor (a memory cell main part, magnetic-head main part)
10 -- Si substrate
11 -- SiO2 Film
12 -- Co film (lower electrode)
13 -- Tunnel insulator layer
14 -- Co super-thin film (up electrode)
15 -- Barrier film
16 17 -- Backup film
18 -- Barrier film
21 -- Collector (semiconductor region)
22 -- Base
23 -- Emitter (magnetic-substance electrode)
31 -- Si substrate (semiconductor region)
32 -- SiO2 Film
33 39 -- Backup film
34 38 -- Barrier film
35 37 -- Co super-thin film (magnetic-substance electrode)
36 -- Tunnel insulator layer
41 -- Semiconductor substrate (semiconductor region)
41n -- N-type-semiconductor substrate (semiconductor region)
42 43 -- Magnetic-substance electrode
44 -- Gate electrode
45 -- Semiconductor layer (undoping)
46 p--p type half-conductor layer (semiconductor region)
46n -- N-type-semiconductor layer (semiconductor region)
46 i--i type half-conductor layer (semiconductor region)
47 -- Tunnel insulator layer
48 -- Magnetic layer (magnetic-substance field)
49 -- Ferromagnetic layer
50 -- Semiconductor layer (semiconductor region)
C1 -- Stray capacity
C2 -- Input capacitance
BL -- Bit line
WL -- Word line

[Translation done.]

TECHNICAL FIELD

[The technical field to which invention belongs] this invention relates to the magnetic-substance element which used the magnetic-substance electrode as a magnetic device and electrodes, such as the magnetic head and magnetic memory.

[Translation done.]

* NOTICES *

Japan Patent Office is not responsible for any damages caus d by the use of this translation.

1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

PRIOR ART

[Description of the Prior Art] The densification of magnetic recording and improvement in the speed have many places which are located in a line with improvement of a magnetic-recording medium, and are undertaken to progress of a magnetic recording medium, and progress of the magnetic head used for the writing and read-out of magnetic recording especially.
[0003] In recent years, small [of a magnetic-recording medium] and large capacity-ization are progressing. With such small or large-capacity-izing, the relative velocity of a magnetic-recording medium and the magnetic head for read-out becomes small, and the time rate of change (output) of flux density is becoming small.
[0004] Even in such a case, development of a huge magnetoresistance-effect head (GMR head) is advanced to the MAG for read-out new type which can take out a big output as DDO. The GMR head has the outstanding property that a magnetic-reluctance ratio (MR ratio) is larger than the conventional MR head.
[0005] As such a GMR head, as shown in drawing 26 , a base layer consists of magnetic cascade screens, and the thing using the tunnel pouring type hot electron transistor to which pouring of the electron to a base layer is performed through a tunnel junction attracts attention quickly, for example.
[0006] Furthermore, as a GMR head which shows MR ratio [being extraordinarily large (several 100%)], as shown in drawing 27 , the base consists of magnetic cascade screens and the thing using the Schottky pouring type hot electron transistor to which pouring of the electron to a base layer is performed through the Schottky barrier is also reported, for example.
[0007] The information read from the magnetic-recording medium by the magnetic heads, such as a GMR head, is used after being read into the semiconductor memory in a computer (for example, DRAM, SRAM).
[0008] Although semiconductor memory has the property which was excellent in many, it also has the big fault of consuming a lot of power for information maintenance. In recent years, as semiconductor memory with the unnecessary power for information maintenance, although development of a flash memory, FRAM, etc. is furthered, all are rewritten and it has the big fault that the number of times is limited.
[0009] On the other hand, development of MAG memory (MRAM) rewritable in an infinite time can also be begun substantially. For the realization, the material and the element which show big MR ratio need to be developed.
[0010] As an element which shows bigger MR ratio than a spin bulk film (the number of laminatings is the magnetic cascade screen of 2), the magnetic-substance tunnel junction element and the hot electron transistor by which the base layer mentioned above was constituted from a magnetic cascade screen attract attention.
[0011] Moreover, the attempt which use a magnetic-substance tunnel junction element or a hot electron transistor independently, and the magnetic head and magnetic memory are formed in recent years, and also forms the magnetic head and magnetic memory combining them and a MOS transistor has begun. The element (GMR element) the reason indicates MR ratio with big magnetic-substance tunnel junction

element, hot electron transistor, etc. to be is because it does not have power gain.
[0012] However, there are the following problems in the magnetic head and the magnetic memory which were constituted combining the GMR element and the MOS transistor. Magnetic memory is mentioned as an example and this problem is explained concretely.
[0013] The magnetic memory cell which becomes drawing 28 from a conventional magnetic-substance tunnel junction element and a conventional MOS transistor is shown. This magnetic memory cell has composition which replaced the capacitor of the usual DRAM cell with the magnetic-substance tunnel junction element.
[0014] As for a magnetic-substance tunnel junction element and 82, the inside of drawing and 81 show the word line stray capacity [WL / a bit line and] / according / 83 / an MOS transistor and / C1 / to a bit line in comparison resistance and BL. Moreover, the word line WL is connected to the source of a constant voltage which is not illustrated. The value with the level of this source of a constant voltage higher than the threshold voltage of MOS transistor 82 is chosen.
[0015] The magnetization means which is not illustrated performs informational (1 0) writing by carrying out magnetization of the magnetic-substance tunnel junction element 81 to parallel or anti-parallel.
[0016] Moreover, informational read-out uses that magnetization changes the magnetic reluctance of the magnetic-substance tunnel junction element 81 by parallel or anti-parallel. As for magnetic reluctance, the way in case magnetization is anti-parallel becomes high. The value of magnetic reluctance in case magnetization is anti-parallel is chosen as the value of the comparison resistance 83.
[0017] Therefore, when magnetization is anti-parallel, magnetic reluctance is large, and the voltage drop by the comparison resistance 83 detected with a sense amplifier will become large. Conversely, when magnetization is parallel, magnetic reluctance is small, and the voltage drop by the comparison resistance 83 detected with a sense amplifier serves as a small potato's. Thus, it becomes possible to perform informational read-out by the size of the voltage drop by the comparison resistance 83 detected with a sense amplifier.
[0018] By the way, the stray capacity C1 by the bit line BL is about 300 fFs. For this reason, in order to make CR time constant small and to perform read-out in time about below nsec, the value of the comparison resistance 83 must be less than [abbreviation 3kohm].
[0019] This resistance is 30microomegacm2 per unit area, when the size of the tunnel junction of the magnetic-substance tunnel junction element 81 is set to 1micrometerx1micrometer. It corresponds and is a very small value.
[0020] Here, they are 30microomegacm2 per unit area by making a tunnel insulator layer thin. Although it is possible to form a tunnel junction, there are the following problems.
[0021] Since several 100mV voltage change is required for read-out by the sense amplifier, a tunnel junction must have several 100mV pressure-proofing.
[0022] However, they are 30microomegacm2 per unit area. Since the tunnel insulator layer is thin, it is difficult the tunnel junction to be easy to generate dielectric breakdown and to give the pressure-proofing which is several 100mV.
[0023] Therefore, the conventional magnetic memory had the problem that it was difficult to make read-out speed quick. Such a problem will become still more remarkable if junction size becomes submicron. In addition, although stray capacity (-300fF) by the word line is also ******(ed), since strong resistance like the comparison resistance 83 is not connected to the word line, it is satisfactory.
[0024] By the way, although the conventional magnetic-substance tunnel junction element showed big MR ratio exceeding 30% in low-battery field several 10mV or less, it had the problem that MR ratio will fall to several% or less, according to the spin flip phenomenon of a tunnel electron in practical use voltage field several 100mV or more.

[Translation done.]

TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention] Like ****, the resistance of a magnetic-substance tunnel junction element in case magnetization is anti-parallel was chosen as a value of the comparison resistance connected to the bit line by the magnetic memory using the conventional magnetic memory cell which consists of a magnetic-substance tunnel junction element and an MOS transistor.
[0026] In order to make read-out speed quick, it is necessary to make the value of comparison resistance small and to make CR time constant small. For that purpose, it is necessary to make thin the tunnel insulator layer of a magnetic-substance tunnel junction element.
[0027] however -- if a tunnel insulator layer is made thin -- dielectric breakdown -- generating -- being easy -- it comes out that it is equal to a voltage change required for read-out by the sense amplifier, and it hears -- it becomes For this reason, the conventional magnetic memory had the problem that it was difficult to make read-out speed quick.
[0028] Moreover, the conventional magnetic-substance tunnel junction element had the problem that sufficient MR ratio was not obtained according to the spin flip phenomenon of a tunnel electron, in practical use voltage field several 100mV or more.
[0029] this invention was made in consideration of the above-mentioned situation, and the place made into the purpose is to offer the magnetic device using the GMR element with a quick read-out speed.
[0030] Moreover, other purposes of this invention are to offer the magnetic-substance element which can suppress property degradation resulting from the spin flip phenomenon of the electron in a practical use voltage field.

[Translation done.]

MEANS

[Means for Solving the Problem] [Elements of the Invention] -- in order to attain the account purpose of a top, it connects with the gate of an MOS transistor and this MOS transistor, and the magnetic device (magnetic head) concerning this invention is characterized by having a GMR element as a magnetic-head main part (claim 1)
[0032] Moreover, it connects with the gate of an MOS transistor and this MOS transistor, and other magnetic devices (magnetic memory) concerning this invention are here where the memory cell which consists of a GMR element as a memory cell main part is characterized by carrying out array formation at the shape of a matrix (claim 2), and can realize RAM by adding the magnetization control means which control the direction of magnetization of a GMR element in the above-mentioned magnetic memory (claim 3).
[0033] It is desirable that connect with the source of a constant voltage through a GMR element, and the gate of an MOS transistor is grounded through the 1st resistance here, the source of the aforementioned MOS transistor is connected to the 2nd resistance in series, and the drain of an MOS transistor is grounded (claim 4).
[0034] Moreover, it is desirable that a GMR element is a magnetic tunnel junction element, or a base layer is the hot electron transistor formed by the magnetic cascade screen (claim 5).
[0035] In this case, it is desirable that the electrode of a magnetic tunnel junction element is formed by the cascade screen of a magnetic film or a magnetic film, and an insulator layer (claim 6). Here, as for a magnetic film, it is desirable that thickness is a magnetic-substance super-thin film 5nm or less.
[0036] Moreover, it is desirable that the emitter layer of a hot electron transistor is formed by the strontium-titanate film by which Nb was doped (claim 7).
[0037] Moreover, the magnetic-substance element concerning this invention (claim 8) is characterized by having the poured in field which consists of the semiconductor region or paramagnetism metal field where the electron current which carried out spin polarization is poured in through the potential barrier over an electron from the magnetic-substance electrode containing a magnetic-substance super-thin film, and this magnetic-substance electrode.
[0038] Here, the thickness of a super-thin film [magnetic substance] has 0.5nm or more desirable 5nm or less (claim 9), and 0.6nm or more its 2nm or less is more desirable.
[0039] Moreover, when a poured in field is a semiconductor region, it is good as a potential barrier to use a tunnel junction, the Schottky barrier, or MIS junction. (Claim 10) When a poured in field is a paramagnetism metal field, it is good as a potential barrier to use a tunnel junction again. (Claim 11) You may use again what consists of a cascade screen of a magnetic-substance super-thin film and the barrier film to an electron as a magnetic-substance electrode (claim 12). As a barrier film, if it works as barrier, there is no limit in the membrane type, for example, an insulator layer, a semiconductor film, a semimetal film, and a dissimilar-metal film can be used.

[Translation done.]

OPERATION

According to the [operation] this invention (claims 1-7), CR time constant leading to a time delay is determined by resistance and the gate capacitance of a GMR element. This gate capacitance is fully small compared with wiring capacity, such as a bit line.
[0041] Therefore, since CR time constant leading to a time delay becomes smaller enough than conventional it according to this invention (claims 1-7), a magnetic device with a quick read-out speed can be realized.
[0042] Moreover, according to research of this invention person, it turns out that there are the following features in a magnetic-substance super-thin film (thickness : 0.5-5nm). That is, if the potential barrier over electrons, such as tunnel combination, Schottky combination, and MIS junction, is formed using a magnetic-substance super-thin film, the s-electron in a magnetic-substance super-thin film will be quantized by the dispersed energy level. At this time, the energy levels differed by the rise spin electron and the down spin electron, and, moreover, it turns out that the energy difference is made to the very large value of about 1eV.
[0043] For this reason, when impressing voltage to a magnetic-substance super-thin film and pouring an electron into the poured in field of a semiconductor region or a paramagnetic-material field through a potential barrier from this magnetic-substance super-thin film, even if it impresses the voltage of a practical use voltage field several mV or more to a magnetic-substance super-thin film, the electronic group to which electronic spin was equal, i.e., the electron current which carried out spin polarization, can be poured into a poured in field.
[0044] Therefore, according to this invention (claims 8-12) based on such knowledge, the magnetic-substance element which can suppress property degradation resulting from the spin flip phenomenon of the electron in a practical use voltage field can be realized now.
[0045]
[Embodiments of the Invention] Hereafter, the gestalt (henceforth an operation gestalt) of operation of this invention is explained, referring to a drawing.
[0046] (1st operation gestalt) The magnetic memory cell which becomes <u>drawing 1</u> from the magnetic-substance tunnel junction element concerning the 1st operation gestalt of this invention and an MOS transistor is shown.
[0047] One shows the magnetic-substance tunnel junction element among drawing, and 2 shows the resistance for [3 / an MOS transistor and] gate-voltage generating in comparison resistance and 4 (gate resistance). Moreover, in BL, the word line stray capacity [WL / a bit line and] / according / C1 / to a bit line and C2 show the input capacitance of MOS transistor 2.
[0048] A word line WL is connected to the source of a constant voltage which is not illustrated, and the value with the level of this source of a constant voltage higher than the threshold voltage of MOS transistor 2 is chosen. Moreover, the value of magnetic reluctance when magnetization of the magnetic-substance tunnel junction element 1 is parallel to the value of the gate resistance 4 is chosen. Magnetization of the magnetic-substance tunnel junction element 1 is performed by the magnetization means (for example, thing which current is passed [thing] to wiring and generates a magnetic field)

which is not illustrated.
[0049] The point that the magnetic memory cell of this operation gestalt mainly differs from the conventional magnetic memory cell shown in drawing 16 is to connect the end of the magnetic-substance tunnel junction element 1 to the gate of MOS transistor 2, and connect the other end to a word line WL.
[0050] Since the input capacitance C2 of MOS transistor 2 is about 1 fF, even if the magnetic reluctance of the magnetic-substance tunnel junction element 1 when magnetization is parallel is about 1 M omega, a question serves as a nsec grade at the time of delay of read-out of the information decided by the time constant of an input capacitance C2 and the magnetic-substance tunnel junction element 1.
[0051] On the other hand, since it has not connected with the magnetic-substance tunnel junction element 81 like the conventional comparison resistance 83, if the comparison resistance 3 is stronger than the on resistance of MOS transistor 2, it can be done small arbitrarily. For this reason, even if the values of stray capacity C1 are 300fF(s), the time delay of read-out of the information decided by the time constant of stray capacity C1 and the comparison resistance 3 serves as a nsec grade.
[0052] Since the time delay of informational read-out can be suppressed to a nsec grade in this way according to this operation gestalt, the magnetic memory cell using the GMR element in which read-out of high-speed information is possible can be realized. Moreover, the high-speed magnetic memory apparatus (RAM) which can read information in time about nsec can be realized now by carrying out array formation of such a magnetic memory cell at the shape of a matrix. In addition, in the case of ROM, the magnetization means is unnecessary.
[0053] By the way, although MR ratio of a magnetic-substance tunnel junction element reported now is about 20% at a room temperature, since dispersion exists in the threshold voltage and gain of an MOS transistor, in order to distinguish the content of information of a memory cell correctly, it is desirable to use the large GMR element of MR ratio.
[0054] as a GMR element with big MR ratio -- recent years and LaSrMnO3 etc. -- the magnetic-substance tunnel junction element using the magnetic-substance electrode which consists of an oxide magnetic compact attracts attention In these oxide magnetic compacts, since conduction electron is carrying out spin polarization about 100%, big MR ratio is obtained.
[0055] However, we are anxious about utilization for the reasons nil why the big magnetic field for operating only at low temperature and flux reversal is required for this kind of magnetic-substance tunnel junction element etc.
[0056] According to research of the inside artificer of such a situation etc., it found out that MR ratio increased as a magnetic-substance electrode by using the cascade screen of a magnetic-substance super-thin film several nm or less or a magnetic-substance super-thin film, and an insulator layer. The principle is described below.
[0057] In ferromagnetic metals, such as Fe, Co, and nickel, as shown in drawing 2 , the electron of strong d band of localization nature and s band near a free electron lives together. Although the electron of d band is carrying out spin polarization near 100% so that drawing 2 may show, the polarizability of the electron of s band is a low.
[0058] After this, the reason nil why MR ratio of the magnetic tunnel junction element using the magnetic-substance electrode which consists of a ferromagnetic metal is as small as about 20% is considered because the contribution to the tunnel current of a small s-electron of polarizability is large. Therefore, it is thought by decreasing the contribution to the tunnel current of an s-electron by a certain method that MR ratio can be increased.
[0059] By the way, in a super-thin film with a thickness of several nm, movement of the electron of the direction of thickness (the direction of z) is quantized as known well, and the energy is [Equation 1].

$$E = \frac{\hbar^2}{2m}\left(k_x^2 + k_y^2\right) + E_{zn}$$

$$E_{zn} = \frac{\hbar^2}{2m}\left(\frac{n\pi}{l}\right)^2 \qquad (1)$$

[0060] A next door and a density of states become stair-like as shown in drawing 3 . In addition, l is showing thickness in the formula (1). On the other hand, it is the angular dependence [several 2] of a tunnel current.

$$J_\theta \propto \exp[-\beta^2 \sin^2 \theta],$$

$$\text{ただし}\quad \beta^4 = 2ms^2 E_F{}^2 / \hbar^2 (E_x - E), \qquad (2)$$

[0061] When it ******, as the wave number vector of the electron which tunnels an insulator layer is shown in drawing 4 , it is a perpendicular (thetac -10 degree) mostly, and it turns out that only the electron of the portion which gave the slash among the states of drawing 3 contributes to a tunnel current in a tunnel junction side. In addition, in the formula (2), s shows the thickness of a tunnel obstruction.
[0062] Here, the energy width of face of the portion which gave the slash is about 100 meV(s), and, in the case of l= 4nm, is Fermi energies EF. If about 5eV, it is Fermi energy EF. The energy interval of the portion which gave the slash in near is as large as about 1.0eV. That is, the s-electron in a magnetic-substance super-thin film is served just like the electron in an insulator layer in a tunnel junction, and does not contribute to a tunnel current.
[0063] In addition, although thickness of a super-thin film [magnetic substance] was set to 4nm, generally 5nm or less, then a tunnel current can be lessened here. In short, it is Fermi energy EF. What is necessary is for the energy interval of the portion which gave the slash in near to become large, and just to choose the thin thickness which an s-electron stops contributing to a tunnel current.
[0064] However, since sheet resistance will increase if only a magnetic-substance super-thin film is used for an electrode, as shown in drawing 5 , it is desirable to constitute a magnetic-substance electrode from a magnetic-substance super-thin film 8 and a conductive backup film 6 with sufficient thickness.
[0065] Although it is necessary to form the barrier film 7 which consists of an insulator between the magnetic-substance super-thin film 8 and the backup film 6 in order not to spoil the two-dimensional nature (2D EG) of the magnetic-substance super-thin film 8 in that case, the thickness of the barrier film 7 must fully be thinner than that of a tunnel insulator layer. In addition, five show Si substrate among drawing.
[0066] Moreover, it is also possible to use the cascade screen of the magnetic-substance super-thin film 8 for a magnetic-substance super-thin film, as shown not only in a monostromatic but in drawing 6 so that old explanation may show. Also in such a case, the thickness of the barrier film 7 needs to be thinner than that of a tunnel insulator layer enough.
[0067] As a magnetic-substance tunnel junction element 1, as shown, for example in drawing 7 , what has a Co/AlOx/Co tunnel junction is raised.
[0068] When this is explained according to a manufacturing process, it is SiO2 with a thickness of 5nm to the front face of the Si (100) substrate 10 first. A film 11 is formed by the oxidizing [thermally] method.
[0069] Next, SiO2 The Co film 12 with 50nm [in thickness as a lower electrode] and a width of face of 0.2mm is formed by the vacuum deposition method on a film 11. Here, the degree of vacuum in the case of vacuum deposition and substrate temperature are set as 1x10-8torr and 77K, respectively. Furthermore, the external magnetic field of 500Oe is impressed and, on the other hand, it is made equal [a magnetic easy shaft] to **.
[0070] Next, after forming aluminum film with a thickness of 1.2nm by the vacuum deposition method on the Co film 12, substrate temperature is returned to a room temperature, the A1 above-mentioned film is continuously oxidized by the glow discharge in the inside of oxygen atmosphere, and the tunnel insulator layer 13 which consists of Alx O is formed. The degree of vacuum in the case of vacuum deposition and substrate temperature are the same as a front.
[0071] Next, substrate temperature is again set as 77K, and the Co super-thin film 14 with 4nm [in thickness as an up electrode] and a width of face of 0.2nm is formed by the vacuum deposition method on the tunnel insulator layer 13. The degree of vacuum in the case of vacuum deposition is the same as a

front.
[0072] next, the front face of the Co [after returning substrate temperature to a room temperature] super-thin film 14 -- the inside of the oxygen atmosphere of 1x10-3torr -- **** during 1 minute -- the barrier film 15 is formed in the front face of the Co super-thin film 14 by things
[0073] Finally, the backup film 16 with a thickness of 50nm it is thin from Au is formed on the barrier film 15.
[0074] Thus, the magnetoresistance effect of the created magnetic-substance tunnel junction element was measured. This measurement was performed by impressing an external magnetic field in a tunnel junction side using the AC bridge.
[0075] The measurement result is shown in drawing 8 . The magnetic-reluctance property reflecting the magnetization curve is seen, and MR ratio is about 26%. Moreover, the absolute value of the bond resistance under a saturation magnetic field was about 20ohms.
[0076] The cross section of the magnetic-substance tunnel junction element which becomes drawing 9 from other Co/AlOx/Co tunnel junctions is shown. In addition, the same sign as drawing 7 is given to the magnetic-substance tunnel junction element of drawing 7 , and the corresponding portion, and detailed explanation is omitted.
[0077] A different point from the magnetic-substance tunnel junction element of drawing 7 uses the Co super-thin film 14 not only for an up electrode but for a lower electrode, and is to have formed the backup film 17 and the barrier film 18 also in the lower electrode side further. Cu film with a thickness of 50nm is used as a backup film 17. Thus, a tunnel junction is formed also in a lower electrode side.
[0078] Cu film which is the backup film 17 sets substrate temperature to 77K, and forms it by the vacuum deposition method, and the barrier film 18 returns substrate temperature to a room temperature after formation of the backup film 17, and forms it by exposing the backup film 17 into the oxygen atmosphere of 1x10-3torr for 1 minute. The formation method of other films is the same as the case of the element of drawing 7 .
[0079] Although the bond resistance under a saturation magnetic field was 22ohms when the magnetoresistance effect of this element was measured by the same method as the case of the magnetic-substance tunnel junction element of drawing 7 , MR ratio was increasing to 35%.
[0080] Moreover, in the magnetic-substance tunnel junction element of drawing 7 , the magnetic-substance tunnel junction element which transposed the Co super-thin film with a thickness of 4nm which is an up electrode to Co film with a thickness of 50nm was formed as an example of comparison. The formation applies to it of the magnetic-substance tunnel junction element of drawing 7 correspondingly.
[0081] Although the bond resistance under a saturation magnetic field was 18ohms when the magnetoresistance effect of this element was measured by the same method as the magnetic-substance tunnel junction element of drawing 7 , MR ratio was 15% and was smaller than drawing 7 and MR ratio of the element of drawing 8 .
[0082] (2nd operation gestalt) The magnetic memory cell which starts the 2nd operation gestalt of this invention at drawing 10 is shown. In addition, the same sign as drawing 1 is given to the magnetic memory cell of drawing 1 , and the corresponding portion, and detailed explanation is omitted.
[0083] This operation gestalt is the example which used the hot electron transistor as a GMR element. A hot electron transistor is a GMR element which shows bigger MR ratio than a magnetic-substance tunnel junction element. MR ratio of a hot electron transistor exceeds 200%. Therefore, it becomes easier to read the information on a memory cell correctly, and it can lessen a read error.
[0084] However, the current gain of a hot electron transistor will be small, and, in the case of the grounded base, a collector current will decrease by 1 or more figures from an emitter current.
[0085] For this reason, like the case of a magnetic-substance tunnel junction element, in order to carry out high-speed operation about ns, as shown in drawing 10 </A>, connecting with the gate of MOS transistor 2 is desirable [a hot electron transistor 9 (collector)].
[0086] by the way, the thing for which an emitter current is enlarged for high-speed operation since the current gain in the grounded base is presumed to be at most about 0.1 -- it is desirable

[0087] In order to pass a big emitter current, the Schottky pouring type hot electron transistor of drawing 27 is more desirable than the tunnel pouring type hot electron transistor of drawing 26 .
[0088] Since it forms on the same substrate as a MOS transistor when forming the hot electron transistor of drawing 26 , Si will be used for the material of a collector layer. Although Si layer is sufficient as a collector layer, it is desirable that it is the semiconductor layer with which it is satisfied of the following conditions as an emitter layer. That is, a band gap is large and a low semiconductor layer has desirable membrane formation temperature.
[0089] The reason with desirable membrane formation temperature being low is that there is a possibility that the property of the magnetic cascade screen which is a base layer may deteriorate when membrane formation temperature is high in order to form an emitter layer after a base layer.
[0090] Moreover, the reason with desirable a band gap being large is that it can reduce quantum mechanics-reflection of the base / collector interface by using the high electron of energy.
[0091] As a semiconductor layer which fulfills such two conditions, the n type titanic-acid stolon CHUUMU (STO) layer (Nb dope n type STO layer) by which Nb was doped is most suitable.
[0092] The dependency of the collector to base voltage (VEB) of the emitter current (IE) at the time of using a Nb dope n type STO layer for drawing 11 as an emitter layer is shown.
[0093] impressing about [0.9V] voltage between the collector bases from drawing -- 103 -- A/cm2 It turns out that the emitter current of a grade flows. In this case, supposing a current gain is 0.1, a read time is set to 0.1ns, and even if a current gain is 0.01, it will turn into 1ns of read times.
[0094] (3rd operation gestalt) The magnetic head which starts the 3rd operation gestalt of this invention at drawing 12 is shown. In addition, the same sign as drawing 1 is given to the magnetic memory cell of drawing 1 , and the corresponding portion, and detailed explanation is omitted.
[0095] The magnetic head of this operation gestalt has composition which removed bit line BL, word line WL, and the magnetization means from the magnetic memory cell of drawing 1 .
[0096] In case the magnetic reluctance of the magnetic-substance tunnel junction element 1 scans a magnetic-recording medium top, it can change, and it can read the information written in the magnetic-recording medium by detecting the voltage change corresponding to this with a sense amplifier.
[0097] High-speed read-out also of the magnetic head of this operation gestalt becomes possible for the same reason as the case of the magnetic memory of the 1st operation gestalt.
[0098] (4th operation gestalt) The magnetic head which starts the 4th operation gestalt of this invention at drawing 13 is shown. In addition, the same sign as drawing 10 is given to the magnetic memory cell of drawing 10 , and the corresponding portion, and detailed explanation is omitted.
[0099] The magnetic head of this operation gestalt has composition which removed bit line BL, word line WL, and the magnetization means from the magnetic memory cell of drawing 10 .
[0100] In case the magnetic reluctance of a hot electron transistor 9 scans a magnetic-recording medium top, it can change, and it can read the information written in the magnetic-recording medium by detecting the voltage change corresponding to this with a sense amplifier.
[0101] High-speed read-out also of the magnetic head of this operation gestalt becomes possible for the same reason as the case of the magnetic memory of the 2nd operation gestalt. Moreover, since bigger MR ratio than a magnetic-substance tunnel junction element is obtained, a read error can be lessened.
[0102] According to research of this invention person, in (the 5th operation gestalt) and time, it found out that MR ratio increased as a magnetic-substance electrode by using the cascade screen of a magnetic-substance super-thin film several nm or less or a magnetic-substance super-thin film, and barrier films, such as a dissimilar-metal film.
[0103] Although the electron of strong d band of localization nature and s band near a free electron lives together in ferromagnetic metals, such as Fe, Co, and nickel, as explained previously, the tunnel current is mainly borne by the s-electron.
[0104] It is thought that the cause that MR ratio of a magnetic-substance tunnel junction falls remarkably in a practical use voltage field is because electronic spin is reversed, i.e., an electronic spin flip phenomenon. Therefore, in order to obtain the tunnel junction which shows big MR ratio in a practical use voltage field, it is required to suppress this spin flip phenomenon by a certain method.

[0105] Here, although the s-electron in a magnetic-substance super-thin film was quantized by the dispersed energy level in the tunnel junction as shown in drawing 3 , this invention person found out that the energy levels differed by the rise spin electron and the down spin electron for the first time this time.

[0106] For example, when a Fe super-thin film with a thickness of 1nm is used as a magnetic-substance super-thin film, the difference of the energy level of a rise spin electron and a down spin electron serves as a very big value of about 1eV.

[0107] Thus, in the magnetic-substance tunnel junction using the electrode which consists of a magnetic-substance super-thin film, in order to have to receive inelastic scattering in which about 1eV energy participated in order for a tunnel electron to carry out spin reversal, the probability that a spin flip phenomenon will happen becomes remarkably low.

[0108] It becomes possible to realize the magnetic-substance tunnel junction element which shows big MR ratio which exceeds 10% in a practical use voltage field by such reduction-ization of the probability of occurrence of a spin flip phenomenon.

[0109] In addition, since sheet resistance will increase if only a magnetic-substance super-thin film is used for an electrode, as shown in drawing 5 , it is desirable to constitute a magnetic-substance electrode from a magnetic-substance super-thin film 8 and a conductive backup film 6 with sufficient thickness.

[0110] As previously explained also in this case, in order not to spoil the two-dimensional nature (2D EG) of the magnetic-substance super-thin film 8, it is good to form the thin barrier film 7. Moreover, as shown in drawing 6 , it is also possible to use the cascade screen of the magnetic-substance super-thin film 8, and it is good to form the thin barrier film 7 also in that case.

[0111] Hereafter, the GMR element (tunnel pouring type hot electron transistor) of this operation form is explained concretely.

[0112] The collector 21 (semiconductor region) which consists of n type Si as this GMR element is shown in drawing 14 , The base 22 which consists of a cascade screen of Au film (thickness : 1.5nm) / Fe film (thickness : 1.5nm) / aluminum film (thickness : 10nm), AlOx It has composition which the backup film (un-illustrating) which consists of an Au film (thickness : 100nm) joined to the emitter 23 (magnetic-substance electrode) which consists of a cascade screen of a film (tunnel insulator layer) / Fe film one by one.

[0113] When MR ratio of this GMR element was investigated, it turns out that it depends for the size on the thickness of Fe film of an emitter 23 greatly. this invention person created three kinds of GMR elements (d= 0.8nm, 1nm, 2nm) from which the thickness d of Fe film of an emitter 23 differs, and investigated the emitter voltage dependency of the MR ratio.

[0114] The result is shown in drawing 15 . Measurement was performed in the environment of temperature 77K. Moreover, as shown in drawing 14 , negative emitter voltage was impressed to the emitter 23 to the collector 21. Drawing 15 shows that MR ratio is so large that the thickness d of Fe film of an emitter 23 is thin also on the same emitter voltage.

[0115] Moreover, this invention person investigated the thickness dependency of Fe film of the emitter 23 of MR ratio. The result is shown in drawing 16 . In addition, emitter voltage is 1V. Moreover, the degree of spin polarization for which it asked from MR ratio using the conduction parameter in the base reported until now is also shown in drawing.

[0116] From drawing 16 , at least 5nm will increase MR ratio rapidly, if it goes down 2nm, although MR ratio is obtained, for example, emitter (Fe) thickness exceeds double precision (100%) in 0.8nm, and MR ratio falls rapidly by 0.6nm, and if 0.5nm is gone down, MR ratio will no longer be obtained.

[0117] Moreover, it turns out that the degree of spin polarization will become under 0.05 (5%) from drawing if 3nm is exceeded, the degree of spin polarization will increase rapidly on the other hand if 2nm is gone down, for example, 0.4 (40%) is exceeded in 0.8nm.

[0118] 0. The result in 8 nm is almost equal to the degree of spin polarization of the tunnel electron measured in the several mV low-battery field reported until now. That is, if thickness of Fe film of an emitter 23 is set to 1nm or less, even if it impresses about [1V] high voltage, since the tunnel ring of the electron is carried out without hardly carrying out a spin flip, it can pass the electron current which

carried out spin polarization.
[0119] Even if emitter (Fe) thickness has 0.5nm or more desirable 5nm or less, and it impresses about [1V] high voltage, i.e., the voltage of a practical use voltage field, to an emitter 23 in this way from the above result by [with 0.6nm or more more desirable 2nm or less] thin-film-izing Fe film of an emitter 23 according to this operation gestalt, the GMR element which shows MR ratio big enough can be realized.
[0120] (6th operation gestalt) Drawing 17 is the cross section showing the magnetic-substance tunnel junction element concerning the 6th operation gestalt of this invention.
[0121] When this is explained according to a manufacturing process, it is SiO2 with a thickness of 5nm on the Si (100) substrate 31 (semiconductor region) first. A film 32 is formed. Next, substrate temperature is set as 77K and it is SiO2. The backup film 33 which consists of Cu is formed on a film 32. Then, it returns to a room temperature and the barrier film 34 is formed in the front face of the backup film 33 by oxidization for [in the inside of the oxygen atmosphere of 1x110-6Torr] 1 minute.
[0122] Next, the Co super-thin film 35 with a thickness [as a lower electrode] of 0.8nm is formed with vacuum deposition on the barrier film 34. At this time, the external magnetic field of 500e is impressed and, on the other hand, it is made equal [a magnetic easy shaft] to **. Moreover, the degree of vacuum in the case of vacuum deposition and substrate temperature are 1x10-8torr and 77K, respectively.
[0123] Next, after forming aluminum film (un-illustrating) with a thickness of 1.2nm on the Cu super-thin film 35, substrate temperature is returned to a room temperature, the A1 above-mentioned film is continuously oxidized by the glow discharge in the inside of oxygen atmosphere, and the tunnel insulator layer 36 which consists of Alx O is formed. The degree of vacuum in the case of vacuum deposition and substrate temperature are the same as a front.
[0124] Next, substrate temperature is again set as 77K, and the Co super-thin film 37 with a thickness [as an up electrode] of 1nm is formed by the vacuum deposition method on the tunnel insulator layer 36. The degree of vacuum in the case of vacuum deposition and substrate temperature are the same as a front.
[0125] next, the front face of the Co [after returning substrate temperature to a room temperature] super-thin film 37 -- the inside of the oxygen atmosphere of 1x10-6torr -- **** during 1 minute -- the barrier film 38 is formed in the front face of the Co super-thin film 37 by things
[0126] Finally, the backup film 39 with a thickness of 50nm it is thin from Au is formed on the barrier film 38.
[0127] Thus, the magnetoresistance effect of the created magnetic-substance tunnel junction element was measured. This measurement was performed by impressing an external magnetic field in a tunnel junction side using the AC bridge.
[0128] Consequently, the magnetic-reluctance property reflecting the magnetization curve is seen, and MR ratio is about 30%. Moreover, the absolute value of the bond resistance under a saturation magnetic field was about 20ohms.
[0129] Moreover, what transposed the up electrode and the lower electrodes 35 and 37 of a magnetic-substance tunnel junction element of this operation gestalt to Co film with a thickness of 50nm was formed as an example of comparison. The formation applies to it of this operation gestalt correspondingly.
[0130] Although the bond resistance under a saturation magnetic field was 18ohms when the same method estimated the magnetoresistance effect of the example of comparison, MR ratio was 5% and was far smaller than MR ratio of the magnetic-substance tunnel junction element of this operation gestalt.
[0131] (7th operation gestalt) Drawing 18 is the cross section showing the magnetic-substance element concerning the 7th operation gestalt of this invention.
[0132] Among drawing, 41 show the semiconductor substrate (semiconductor region), the 1st magnetic-substance electrode 42 which consists of a magnetic-substance super-thin film is formed in the end side of this semiconductor substrate 41, and the 2nd magnetic-substance electrode 43 which consists of a magnetic-substance super-thin film is formed in the other end side. As a semiconductor substrate, a Fe super-thin film is used, for example as Si substrate and a magnetic-substance super-thin film, for

example.
[0133] The semiconductor substrate 41 and the 1st magnetic-substance electrode 42 form the Schottky barrier, and the semiconductor substrate 41 and the 2nd magnetic-substance electrode 43 form the Schottky barrier similarly. Moreover, the thickness of the 1st and 2nd magnetic-substance electrodes 42 and 43 is 0.5nm or more (0.6 or more [Preferably]) 5nm or less (preferably 2nm or less).
[0134] Thus, according to the constituted magnetic-substance element, if negative voltage is impressed to the 1st magnetic-substance electrode 42 to the 2nd magnetic-substance electrode 43, an electron can be injected into the semiconductor substrate 41 through the Schottky barrier from the 1st magnetic-substance electrode 42, without causing a spin flip phenomenon.
[0135] Therefore, according to this operation gestalt, the electron current Ie which carried out spin polarization toward the 2nd magnetic-substance electrode 43 from the 1st magnetic-substance electrode 42 can be passed now in the semiconductor substrate 41.
[0136] The modification of this operation gestalt is shown in drawing 19 . This shows the structure in the case of passing the electron current Ie in the vertical direction. Moreover, with this operation gestalt, although the monolayer of a super-thin film [magnetic substance] was used as magnetic-substance electrodes 42 and 43, you may use the cascade screen of a magnetic-substance super-thin film and the barrier film to an electron, for example. As a barrier film, if it works as barrier, there is no limit in the membrane type, for example, an insulator layer, a semiconductor film, a semimetal film, and a dissimilar-metal film can be used.
[0137] (Operation gestalt of the octavus) Drawing 20 is the cross section showing the magnetic-substance element concerning the operation gestalt of the octavus of this invention. In addition, the same sign as drawing 18 is given to the magnetic-substance element of drawing 18 , and the corresponding portion, and detailed explanation is omitted (the same about other following operation gestalten).
[0138] This operation gestalt forms the gate electrode 44 in the front face of the semiconductor substrate 41 between the 1st magnetic-substance electrode (source electrode) 42 and the 2nd magnetic-substance electrode (drain electrode) 43, and is to have constituted FET. The semiconductor substrate 41 and the gate electrode 44 form the Schottky barrier.
[0139] It compares, when controlling the electron current in which the rise spin electron and the down spin electron were intermingled, since the electron current Ie which carried out spin polarization is controllable by the gate voltage according to this operation gestalt, and it is a mutual conductance gm. Big FET can be realized now.
[0140] In addition, a gate insulator layer may be formed on the semiconductor substrate 41, and the 1st magnetic-substance electrode (source electrode) 42, the 2nd magnetic-substance electrode (drain electrode) 43, and the gate electrode 44 may be formed on it.
[0141] (9th operation gestalt) Drawing 21 is the cross section showing the magnetic-substance element concerning the 9th operation gestalt of this invention.
[0142] This operation gestalt is the example which applied this invention to Light Emitting Diode, pours in the electron current Ie which carried out spin polarization to the semiconductor substrate 41 of undoping from the 1st magnetic-substance electrode 42, and pours in the hole current Ih which carried out spin polarization to the semiconductor substrate 41 from the 2nd magnetic-substance electrode 43. Thereby, the reunion of an electron and an electron hole happens and luminescence arises.
[0143] Since reunion can be caused by the electron current Ie and the hole current Ih which carried out spin polarization according to this operation gestalt, compared with the case where reunion is caused, voltage required for luminescence is low and can be managed with the electron current and the hole current in which the rise spin electron and the down spin electron were intermingled.
[0144] In addition, the semiconductor layer of undoping of 45 is shown among drawing. Recombination velocity is controllable by the applied voltage of this semiconductor layer 45.
[0145] (10th operation gestalt) Drawing 22 is the cross section showing the magnetic-substance element concerning the 10th operation gestalt of this invention. It is the example in which this operation gestalt also applied this invention to Light Emitting Diode.
[0146] The point that this operation gestalt differs from the 9th operation gestalt is to have constituted

Light Emitting Diode using the impurity dope semiconductor. The 1st magnetic-substance electrode 42 is joined to the n-type-semiconductor substrate 41 through p type semiconductor layer 45p. Moreover, p type semiconductor layer 45p is used instead of the semiconductor layer 45 of undoping. The same effect as the 9th operation gestalt is acquired also with this operation gestalt.
[0147] (11th operation gestalt) Drawing 23 is the cross section showing the magnetic-substance element concerning the 11th operation gestalt of this invention. This operation gestalt is the example which applied this invention to laser. A p type semiconductor layer (semiconductor region) and 46i show the i-type-semiconductor layer (semiconductor region), and inside of drawing and 46p shows 46n (semiconductor region) of n-type-semiconductor layers.
[0148] Since the inverted population can be formed by the electron current Ie and the hole current Ip which carried out spin polarization according to this operation gestalt, compared with the case where the inverted population is formed, voltage (threshold voltage) required for laser oscillation becomes low by the electron current and the hole current in which the rise spin electron and the down spin electron were intermingled.
[0149] (12th operation gestalt) Drawing 24 is the cross section showing the magnetic-substance element concerning the 12th operation gestalt of this invention. This operation gestalt is the example which applied this invention to the spin transistor. 47 show the tunnel insulator layer among drawing, and 48 shows the paramagnetic-material layer (magnetic-substance field). The paramagnetic-material layer 48 is grounded.
[0150] Since the electron current Ie which carried out spin polarization from the 1st magnetic-substance electrode 42 can be injected into the paramagnetic-material layer 48 according to this operation gestalt, compared with the case where the electron current in which the rise spin electron and the down spin electron were intermingled is poured in, a big voltage difference can be generated by between the 2nd magnetic-substance electrode 43 and the paramagnetic-material layers 48.
[0151] (13th operation gestalt) Drawing 25 is the cross section showing the magnetic-substance element concerning the 13th operation gestalt of this invention. This operation gestalt is the example which applied this invention to the hot electron transistor. 49 show the ferromagnetic layer among drawing and 50 shows the semiconductor layer (semiconductor region).
[0152] Since the electron current Ie which carried out spin polarization can be injected into the semiconductor layer 50 through the tunnel insulator layer 47 from the 1st magnetic-substance electrode 42 according to this operation gestalt, bigger MR ratio is obtained compared with the case where the electron current in which the rise spin electron and the down spin electron were intermingled is poured in.

[Translation done.]

EFFECT OF THE INVENTION

[Effect of the Invention] Since CR time constant leading to a time delay can be made small according to this invention (claims 1-7) as explained in full detail above, a magnetic device with a quick read-out speed can be realized.
[0154] Moreover, according to this invention (claims 8-12), the magnetic-substance element which can suppress property degradation resulting from the spin flip phenomenon of the electron in a practical use voltage field can be realized now by using a magnetic-substance super-thin film as a magnetic-substance electrode.

[Translation done.]

CLAIMS

[Claim(s)]
[Claim 1] The magnetic device which is connected to the gate of an MOS transistor and this MOS transistor, possesses the GMR element as a magnetic-head main part, and is characterized by the bird clapper.
[Claim 2] The magnetic device to which the memory cell which is connected to the gate of an MOS transistor and this MOS transistor, and consists of a GMR element as a memory cell main part is characterized by carrying out array formation at the shape of a matrix.
[Claim 3] The magnetic device according to claim 2 characterized by having further the magnetization control means which control the direction of magnetization of the aforementioned GMR element.
[Claim 4] It is the magnetic device according to claim 1 or 2 which it connects with the source of a constant voltage through the aforementioned GMR element, and the gate of the aforementioned MOS transistor is grounded through the 1st resistance, and the source of the aforementioned MOS transistor is connected to the 2nd resistance of low resistance in series rather than the 1st aforementioned resistance, and is characterized by grounding the drain of the aforementioned MOS transistor.
[Claim 5] The aforementioned GMR element is a magnetic device according to claim 1 or 2 characterized by being a magnetic tunnel junction element or a base layer being the hot electron transistor formed by the magnetic cascade screen.
[Claim 6] The electrode of the aforementioned magnetic tunnel junction element is a magnetic device according to claim 5 characterized by being formed by the cascade screen of a magnetic film or a magnetic film, and an insulator layer.
[Claim 7] The emitter layer of the aforementioned hot electron transistor is a magnetic device according to claim 5 characterized by being formed by the strontium-titanate film by which Nb was doped.
[Claim 8] The magnetic-substance element which possesses the poured in field which consists of the semiconductor region or paramagnetism metal field where the electron current which carried out spin polarization is poured in through the potential barrier over an electron, and is characterized by the bird clapper from the magnetic-substance electrode containing a magnetic-substance super-thin film, and this magnetic-substance electrode.
[Claim 9] The thickness of a super-thin film [magnetic substance / aforementioned] is a magnetic-substance element according to claim 8 characterized by 0.5nm or more being 5nm or less.
[Claim 10] The magnetic-substance element according to claim 8 characterized by using a tunnel junction, the Schottky barrier, or MIS junction as the aforementioned potential barrier when the aforementioned poured in field is a semiconductor region.
[Claim 11] The magnetic-substance element according to claim 8 characterized by using a tunnel junction as the aforementioned potential barrier when the aforementioned poured in field is a paramagnetism metal field.
[Claim 12] The aforementioned magnetic-substance electrode is a magnetic-substance element according to claim 8 characterized by the bird clapper from the cascade screen of the aforementioned magnetic-substance super-thin film and the barrier film to an electron.

[Translation done.]

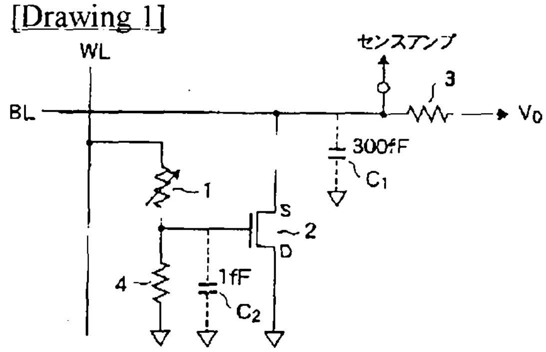
* NOTICES *

Japan Patent Office is not responsible for any damages caused by the use of this translation.

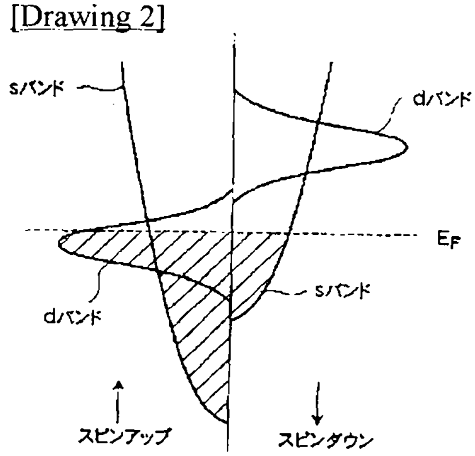
1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

DRAWINGS

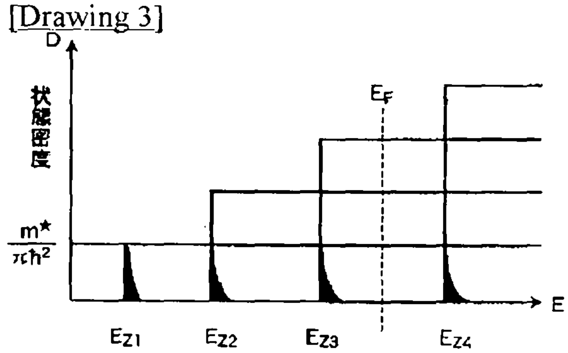
[Drawing 1]



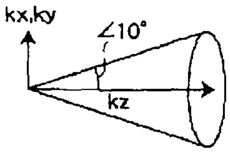
[Drawing 2]



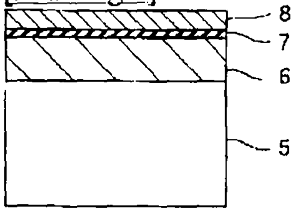
[Drawing 3]



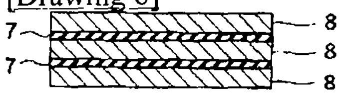
[Drawing 4]



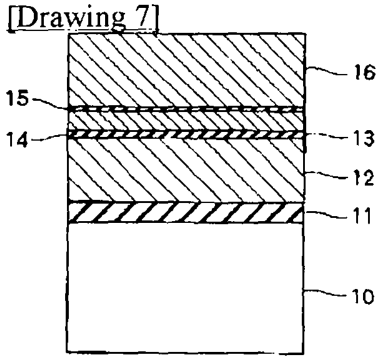
[Drawing 5]



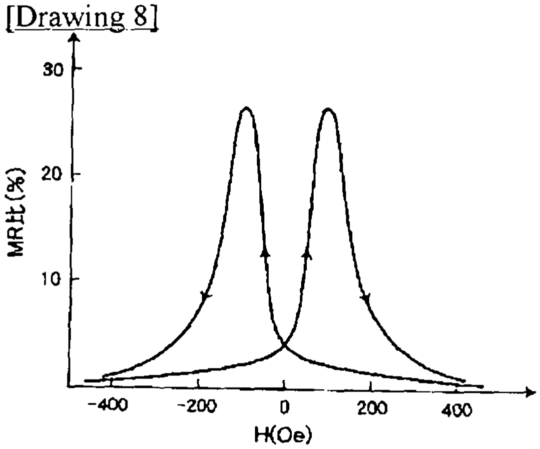
[Drawing 6]



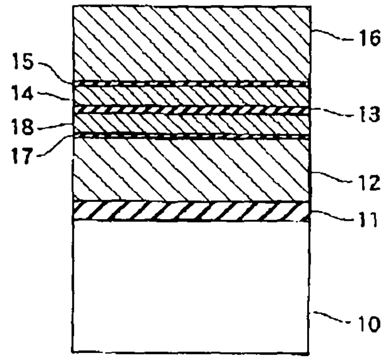
[Drawing 7]



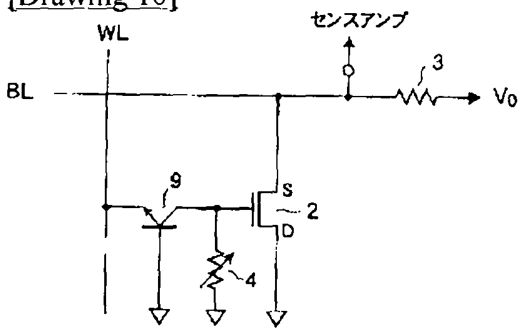
[Drawing 8]



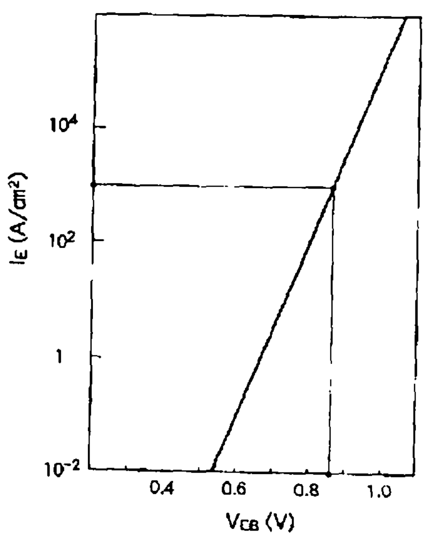
[Drawing 9]



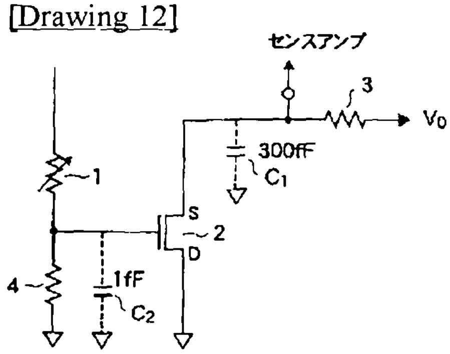
[Drawing 10]



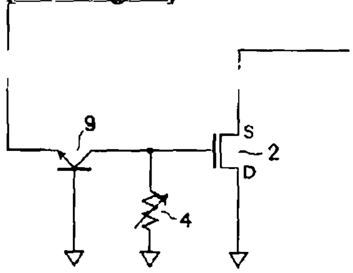
[Drawing 11]



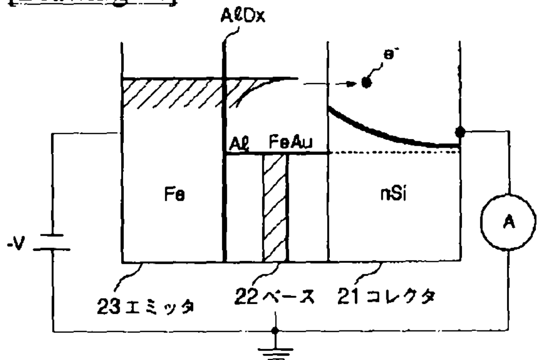
[Drawing 12]



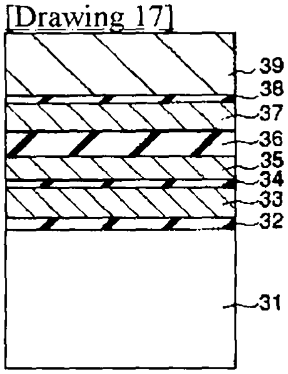
[Drawing 13]



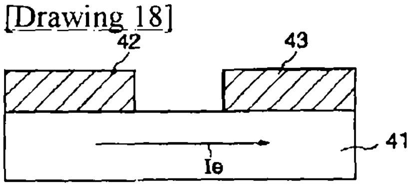
[Drawing 14]



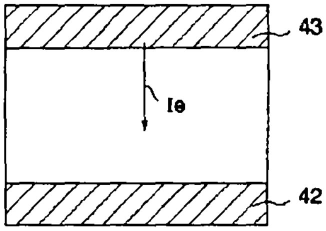
[Drawing 17]



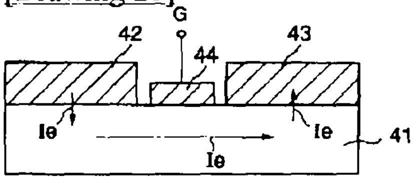
[Drawing 18]



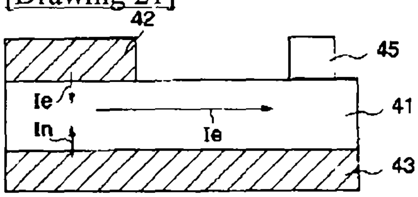
[Drawing 19]



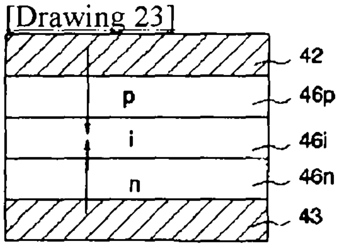
[Drawing 20]



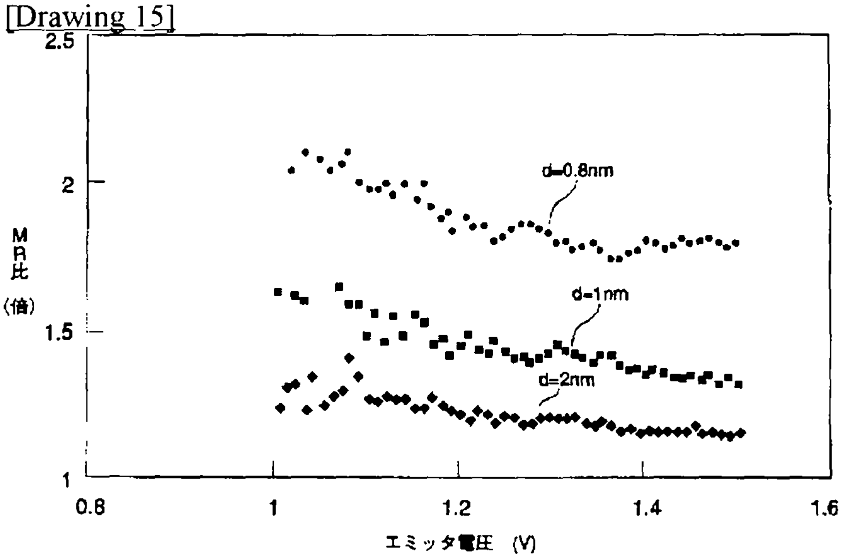
[Drawing 21]



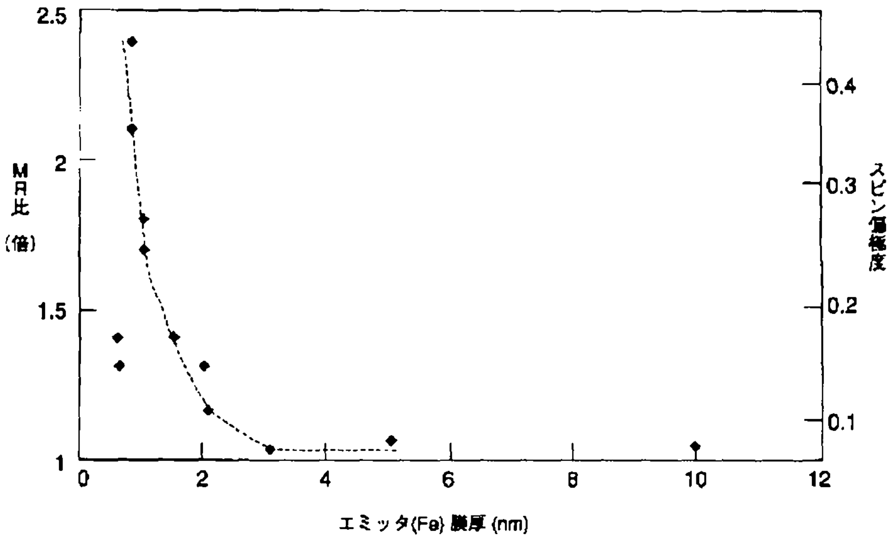
[Drawing 23]



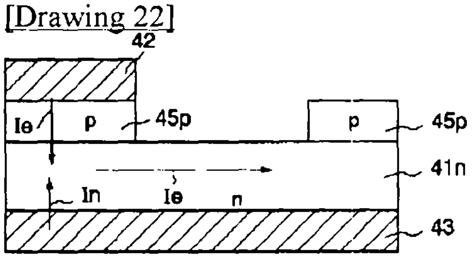
[Drawing 15]



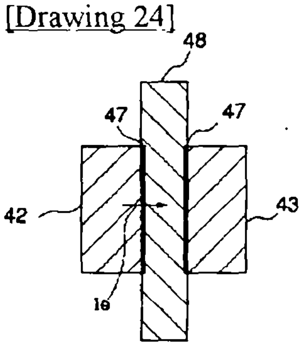
[Drawing 16]



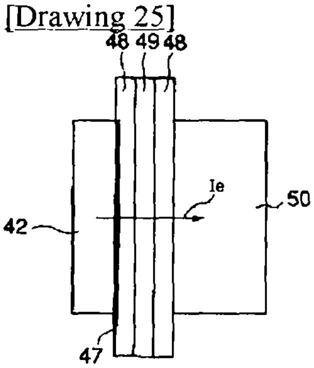
[Drawing 22]



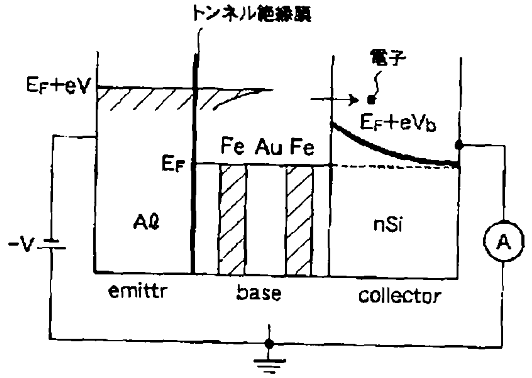
[Drawing 24]



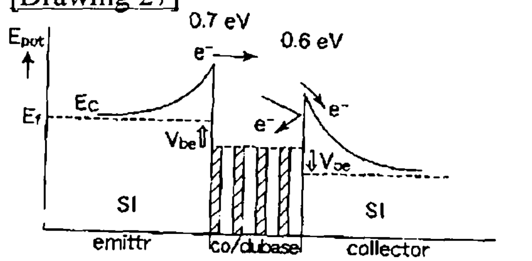
[Drawing 25]



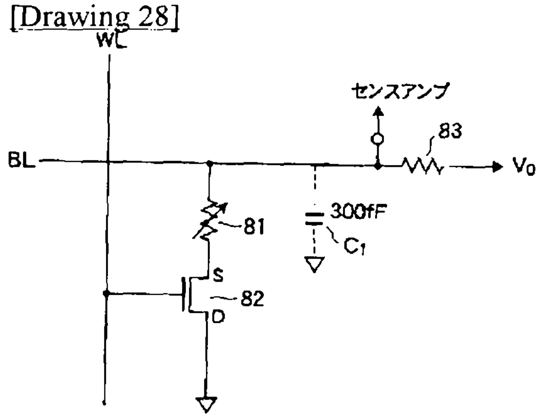
[Drawing 26]



[Drawing 27]



[Drawing 28]



[Translation done.]

gestalt of this invention
[Drawing 25] The cross section showing the magnetic-substance element concerning the 13th operation gestalt of this invention
[Drawing 26] Drawing showing a conventional tunnel pouring type hot electron transistor
[Drawing 27] Drawing showing a conventional Schottky pouring type hot electron transistor
[Drawing 28] Drawing showing the magnetic memory cell which consists of a conventional magnetic-substance tunnel junction element and a conventional MOS transistor
[Description of Notations]
1 -- Magnetic-substance tunnel junction element (a memory cell main part, magnetic-head main part)
2 -- MOS transistor
3 -- Comparison resistance (2nd resistance)
4 -- Gate resistance (1st resistance)
5 -- Si substrate
6 -- Backup film
7 -- Barrier film
8 -- Magnetic-substance super-thin film
9 -- Hot electron transistor (a memory cell main part, magnetic-head main part)
10 -- Si substrate
11 -- SiO2 Film
12 -- Co film (lower electrode)
13 -- Tunnel insulator layer
14 -- Co super-thin film (up electrode)
15 -- Barrier film
16 17 -- Backup film
18 -- Barrier film
21 -- Collector (semiconductor region)
22 -- Base
23 -- Emitter (magnetic-substance electrode)
31 -- Si substrate (semiconductor region)
32 -- SiO2 Film
33 39 -- Backup film
34 38 -- Barrier film
35 37 -- Co super-thin film (magnetic-substance electrode)
36 -- Tunnel insulator layer
41 -- Semiconductor substrate (semiconductor region)
41n -- N-type-semiconductor substrate (semiconductor region)
42 43 -- Magnetic-substance electrode
44 -- Gate electrode
45 -- Semiconductor layer (undoping)
46 p--p type half-conductor layer (semiconductor region)
46n -- N-type-semiconductor layer (semiconductor region)
46 i--i type half-conductor layer (semiconductor region)
47 -- Tunnel insulator layer
48 -- Magnetic layer (magnetic-substance field)
49 -- Ferromagnetic layer
50 -- Semiconductor layer (semiconductor region)
C1 -- Stray capacity
C2 -- Input capacitance
BL -- Bit line
WL -- Word line

[Translation done.]

TECHNICAL FIELD

[The technical field to which invention belongs] this invention relates to the magnetic-substance element which used the magnetic-substance electrode as a magnetic device and electrodes, such as the magnetic head and magnetic memory.

[Translation done.]

PRIOR ART

[Description of the Prior Art] The densification of magnetic recording and improvement in the speed have many places which are located in a line with improvement of a magnetic-recording medium, and are undertaken to progress of a magnetic recording medium, and progress of the magnetic head used for the writing and read-out of magnetic recording especially.
[0003] In recent years, small [of a magnetic-recording medium] and large capacity-ization are progressing. With such small or large-capacity-izing, the relative velocity of a magnetic-recording medium and the magnetic head for read-out becomes small, and the time rate of change (output) of flux density is becoming small.
[0004] Even in such a case, development of a huge magnetoresistance-effect head (GMR head) is advanced to the MAG for read-out new type which can take out a big output as DDO. The GMR head has the outstanding property that a magnetic-reluctance ratio (MR ratio) is larger than the conventional MR head.
[0005] As such a GMR head, as shown in drawing 26 , a base layer consists of magnetic cascade screens, and the thing using the tunnel pouring type hot electron transistor to which pouring of the electron to a base layer is performed through a tunnel junction attracts attention quickly, for example.
[0006] Furthermore, as a GMR head which shows MR ratio [being extraordinarily large (several 100%)], as shown in drawing 27 , the base consists of magnetic cascade screens and the thing using the Schottky pouring type hot electron transistor to which pouring of the electron to a base layer is performed through the Schottky barrier is also reported, for example.
[0007] The information read from the magnetic-recording medium by the magnetic heads, such as a GMR head, is used after being read into the semiconductor memory in a computer (for example, DRAM, SRAM).
[0008] Although semiconductor memory has the property which was excellent in many, it also has the big fault of consuming a lot of power for information maintenance. In recent years, as semiconductor memory with the unnecessary power for information maintenance, although development of a flash memory, FRAM, etc. is furthered, all are rewritten and it has the big fault that the number of times is limited.
[0009] On the other hand, development of MAG memory (MRAM) rewritable in an infinite time can also be begun substantially. For the realization, the material and the element which show big MR ratio need to be developed.
[0010] As an element which shows bigger MR ratio than a spin bulk film (the number of laminatings is the magnetic cascade screen of 2), the magnetic-substance tunnel junction element and the hot electron transistor by which the base layer mentioned above was constituted from a magnetic cascade screen attract attention.
[0011] Moreover, the attempt which use a magnetic-substance tunnel junction element or a hot electron transistor independently, and the magnetic head and magnetic memory are formed in recent years, and also forms the magnetic head and magnetic memory combining them and a MOS transistor has begun. The element (GMR element) the reason indicates MR ratio with big magnetic-substance tunnel junction

element, hot electron transistor, etc. to be is because it does not have power gain.
[0012] However, there are the following problems in the magnetic head and the magnetic memory which were constituted combining the GMR element and the MOS transistor. Magnetic memory is mentioned as an example and this problem is explained concretely.
[0013] The magnetic memory cell which becomes drawing 28 from a conventional magnetic-substance tunnel junction element and a conventional MOS transistor is shown. This magnetic memory cell has composition which replaced the capacitor of the usual DRAM cell with the magnetic-substance tunnel junction element.
[0014] As for a magnetic-substance tunnel junction element and 82, the inside of drawing and 81 show the word line stray capacity [WL / a bit line and] / according / 83 / an MOS transistor and / C1 / to a bit line in comparison resistance and BL. Moreover, the word line WL is connected to the source of a constant voltage which is not illustrated. The value with the level of this source of a constant voltage higher than the threshold voltage of MOS transistor 82 is chosen.
[0015] The magnetization means which is not illustrated performs informational (1 0) writing by carrying out magnetization of the magnetic-substance tunnel junction element 81 to parallel or anti-parallel.
[0016] Moreover, informational read-out uses that magnetization changes the magnetic reluctance of the magnetic-substance tunnel junction element 81 by parallel or anti-parallel. As for magnetic reluctance, the way in case magnetization is anti-parallel becomes high. The value of magnetic reluctance in case magnetization is anti-parallel is chosen as the value of the comparison resistance 83.
[0017] Therefore, when magnetization is anti-parallel, magnetic reluctance is large, and the voltage drop by the comparison resistance 83 detected with a sense amplifier will become large. Conversely, when magnetization is parallel, magnetic reluctance is small, and the voltage drop by the comparison resistance 83 detected with a sense amplifier serves as a small potato's. Thus, it becomes possible to perform informational read-out by the size of the voltage drop by the comparison resistance 83 detected with a sense amplifier.
[0018] By the way, the stray capacity C1 by the bit line BL is about 300 fFs. For this reason, in order to make CR time constant small and to perform read-out in time about below nsec, the value of the comparison resistance 83 must be less than [abbreviation 3kohm].
[0019] This resistance is 30microomegacm2 per unit area, when the size of the tunnel junction of the magnetic-substance tunnel junction element 81 is set to 1micrometerx1micrometer. It corresponds and is a very small value.
[0020] Here, they are 30microomegacm2 per unit area by making a tunnel insulator layer thin. Although it is possible to form a tunnel junction, there are the following problems.
[0021] Since several 100mV voltage change is required for read-out by the sense amplifier, a tunnel junction must have several 100mV pressure-proofing.
[0022] However, they are 30microomegacm2 per unit area. Since the tunnel insulator layer is thin, it is difficult the tunnel junction to be easy to generate dielectric breakdown and to give the pressure-proofing which is several 100mV.
[0023] Therefore, the conventional magnetic memory had the problem that it was difficult to make read-out speed quick. Such a problem will become still more remarkable if junction size becomes submicron. In addition, although stray capacity (-300fF) by the word line is also ******(ed), since strong resistance like the comparison resistance 83 is not connected to the word line, it is satisfactory.
[0024] By the way, although the conventional magnetic-substance tunnel junction element showed big MR ratio exceeding 30% in low-battery field several 10mV or less, it had the problem that MR ratio will fall to several% or less, according to the spin flip phenomenon of a tunnel electron in practical use voltage field several 100mV or more.

[Translation done.]

TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention] Like ****, the resistance of a magnetic-substance tunnel junction element in case magnetization is anti-parallel was chosen as a value of the comparison resistance connected to the bit line by the magnetic memory using the conventional magnetic memory cell which consists of a magnetic-substance tunnel junction element and an MOS transistor.
[0026] In order to make read-out speed quick, it is necessary to make the value of comparison resistance small and to make CR time constant small. For that purpose, it is necessary to make thin the tunnel insulator layer of a magnetic-substance tunnel junction element.
[0027] however -- if a tunnel insulator layer is made thin -- dielectric breakdown -- generating -- being easy -- it comes out that it is equal to a voltage change required for read-out by the sense amplifier, and it hears -- it becomes For this reason, the conventional magnetic memory had the problem that it was difficult to make read-out speed quick.
[0028] Moreover, the conventional magnetic-substance tunnel junction element had the problem that sufficient MR ratio was not obtained according to the spin flip phenomenon of a tunnel electron, in practical use voltage field several 100mV or more.
[0029] this invention was made in consideration of the above-mentioned situation, and the place made into the purpose is to offer the magnetic device using the GMR element with a quick read-out speed.
[0030] Moreover, other purposes of this invention are to offer the magnetic-substance element which can suppress property degradation resulting from the spin flip phenomenon of the electron in a practical use voltage field.

[Translation done.]

MEANS

[Means for Solving the Problem] [Elements of the Invention] -- in order to attain the account purpose of a top, it connects with the gate of an MOS transistor and this MOS transistor, and the magnetic device (magnetic head) concerning this invention is characterized by having a GMR element as a magnetic-head main part (claim 1)
[0032] Moreover, it connects with the gate of an MOS transistor and this MOS transistor, and other magnetic devices (magnetic memory) concerning this invention are here where the memory cell which consists of a GMR element as a memory cell main part is characterized by carrying out array formation at the shape of a matrix (claim 2), and can realize RAM by adding the magnetization control means which control the direction of magnetization of a GMR element in the above-mentioned magnetic memory (claim 3).
[0033] It is desirable that connect with the source of a constant voltage through a GMR element, and the gate of an MOS transistor is grounded through the 1st resistance here, the source of the aforementioned MOS transistor is connected to the 2nd resistance in series, and the drain of an MOS transistor is grounded (claim 4).
[0034] Moreover, it is desirable that a GMR element is a magnetic tunnel junction element, or a base layer is the hot electron transistor formed by the magnetic cascade screen (claim 5).
[0035] In this case, it is desirable that the electrode of a magnetic tunnel junction element is formed by the cascade screen of a magnetic film or a magnetic film, and an insulator layer (claim 6). Here, as for a magnetic film, it is desirable that thickness is a magnetic-substance super-thin film 5nm or less.
[0036] Moreover, it is desirable that the emitter layer of a hot electron transistor is formed by the strontium-titanate film by which Nb was doped (claim 7).
[0037] Moreover, the magnetic-substance element concerning this invention (claim 8) is characterized by having the poured in field which consists of the semiconductor region or paramagnetism metal field where the electron current which carried out spin polarization is poured in through the potential barrier over an electron from the magnetic-substance electrode containing a magnetic-substance super-thin film, and this magnetic-substance electrode.
[0038] Here, the thickness of a super-thin film [magnetic substance] has 0.5nm or more desirable 5nm or less (claim 9), and 0.6nm or more its 2nm or less is more desirable.
[0039] Moreover, when a poured in field is a semiconductor region, it is good as a potential barrier to use a tunnel junction, the Schottky barrier, or MIS junction. (Claim 10) When a poured in field is a paramagnetism metal field, it is good as a potential barrier to use a tunnel junction again. (Claim 11) You may use again what consists of a cascade screen of a magnetic-substance super-thin film and the barrier film to an electron as a magnetic-substance electrode (claim 12). As a barrier film, if it works as barrier, there is no limit in the membrane type, for example, an insulator layer, a semiconductor film, a semimetal film, and a dissimilar-metal film can be used.

[Translation done.]

OPERATION

According to the [operation] this invention (claims 1-7), CR time constant leading to a time delay is determined by resistance and the gate capacitance of a GMR element. This gate capacitance is fully small compared with wiring capacity, such as a bit line.
[0041] Therefore, since CR time constant leading to a time delay becomes smaller enough than conventional it according to this invention (claims 1-7), a magnetic device with a quick read-out speed can be realized.
[0042] Moreover, according to research of this invention person, it turns out that there are the following features in a magnetic-substance super-thin film (thickness : 0.5-5nm). That is, if the potential barrier over electrons, such as tunnel combination, Schottky combination, and MIS junction, is formed using a magnetic-substance super-thin film, the s-electron in a magnetic-substance super-thin film will be quantized by the dispersed energy level. At this time, the energy levels differed by the rise spin electron and the down spin electron, and, moreover, it turns out that the energy difference is made to the very large value of about 1eV.
[0043] For this reason, when impressing voltage to a magnetic-substance super-thin film and pouring an electron into the poured in field of a semiconductor region or a paramagnetic-material field through a potential barrier from this magnetic-substance super-thin film, even if it impresses the voltage of a practical use voltage field several mV or more to a magnetic-substance super-thin film, the electronic group to which electronic spin was equal, i.e., the electron current which carried out spin polarization, can be poured into a poured in field.
[0044] Therefore, according to this invention (claims 8-12) based on such knowledge, the magnetic-substance element which can suppress property degradation resulting from the spin flip phenomenon of the electron in a practical use voltage field can be realized now.
[0045]
[Embodiments of the Invention] Hereafter, the gestalt (henceforth an operation gestalt) of operation of this invention is explained, referring to a drawing.
[0046] (1st operation gestalt) The magnetic memory cell which becomes drawing 1 from the magnetic-substance tunnel junction element concerning the 1st operation gestalt of this invention and an MOS transistor is shown.
[0047] One shows the magnetic-substance tunnel junction element among drawing, and 2 shows the resistance for [3 / an MOS transistor and] gate-voltage generating in comparison resistance and 4 (gate resistance). Moreover, in BL, the word line stray capacity [WL / a bit line and] / according / C1 / to a bit line and C2 show the input capacitance of MOS transistor 2.
[0048] A word line WL is connected to the source of a constant voltage which is not illustrated, and the value with the level of this source of a constant voltage higher than the threshold voltage of MOS transistor 2 is chosen. Moreover, the value of magnetic reluctance when magnetization of the magnetic-substance tunnel junction element 1 is parallel to the value of the gate resistance 4 is chosen. Magnetization of the magnetic-substance tunnel junction element 1 is performed by the magnetization means (for example, thing which current is passed [thing] to wiring and generates a magnetic field)

which is not illustrated.
[0049] The point that the magnetic memory cell of this operation gestalt mainly differs from the conventional magnetic memory cell shown in drawing 16 is to connect the end of the magnetic-substance tunnel junction element 1 to the gate of MOS transistor 2, and connect the other end to a word line WL.
[0050] Since the input capacitance C2 of MOS transistor 2 is about 1 fF, even if the magnetic reluctance of the magnetic-substance tunnel junction element 1 when magnetization is parallel is about 1 M omega, a question serves as a nsec grade at the time of delay of read-out of the information decided by the time constant of an input capacitance C2 and the magnetic-substance tunnel junction element 1.
[0051] On the other hand, since it has not connected with the magnetic-substance tunnel junction element 81 like the conventional comparison resistance 83, if the comparison resistance 3 is stronger than the on resistance of MOS transistor 2, it can be done small arbitrarily. For this reason, even if the values of stray capacity C1 are 300fF(s), the time delay of read-out of the information decided by the time constant of stray capacity C1 and the comparison resistance 3 serves as a nsec grade.
[0052] Since the time delay of informational read-out can be suppressed to a nsec grade in this way according to this operation gestalt, the magnetic memory cell using the GMR element in which read-out of high-speed information is possible can be realized. Moreover, the high-speed magnetic memory apparatus (RAM) which can read information in time about nsec can be realized now by carrying out array formation of such a magnetic memory cell at the shape of a matrix. In addition, in the case of ROM, the magnetization means is unnecessary.
[0053] By the way, although MR ratio of a magnetic-substance tunnel junction element reported now is about 20% at a room temperature, since dispersion exists in the threshold voltage and gain of an MOS transistor, in order to distinguish the content of information of a memory cell correctly, it is desirable to use the large GMR element of MR ratio.
[0054] as a GMR element with big MR ratio -- recent years and LaSrMnO3 etc. -- the magnetic-substance tunnel junction element using the magnetic-substance electrode which consists of an oxide magnetic compact attracts attention In these oxide magnetic compacts, since conduction electron is carrying out spin polarization about 100%, big MR ratio is obtained.
[0055] However, we are anxious about utilization for the reasons nil why the big magnetic field for operating only at low temperature and flux reversal is required for this kind of magnetic-substance tunnel junction element etc.
[0056] According to research of the inside artificer of such a situation etc., it found out that MR ratio increased as a magnetic-substance electrode by using the cascade screen of a magnetic-substance super-thin film several nm or less or a magnetic-substance super-thin film, and an insulator layer. The principle is described below.
[0057] In ferromagnetic metals, such as Fe, Co, and nickel, as shown in drawing 2 , the electron of strong d band of localization nature and s band near a free electron lives together. Although the electron of d band is carrying out spin polarization near 100% so that drawing 2 may show, the polarizability of the electron of s band is a low.
[0058] After this, the reason nil why MR ratio of the magnetic tunnel junction element using the magnetic-substance electrode which consists of a ferromagnetic metal is as small as about 20% is considered because the contribution to the tunnel current of a small s-electron of polarizability is large. Therefore, it is thought by decreasing the contribution to the tunnel current of an s-electron by a certain method that MR ratio can be increased.
[0059] By the way, in a super-thin film with a thickness of several nm, movement of the electron of the direction of thickness (the direction of z) is quantized as known well, and the energy is [Equation 1].

$$E = \frac{\hbar^2}{2m}\left(k_x^2 + k_y^2\right) + E_{zn}$$

$$E_{zn} = \frac{\hbar^2}{2m}\left(\frac{n\pi}{1}\right)^2 \qquad (1)$$

[0060] A next door and a density of states become stair-like as shown in drawing 3 . In addition, l is showing thickness in the formula (1). On the other hand, it is the angular dependence [several 2] of a tunnel current.

$$J_\theta \propto \exp[-\beta^2 \sin^2 \theta],$$

$$\text{ただし} \quad \beta^4 = 2ms^2E_F{}^2 / \hbar^2(E_x - E), \qquad (2)$$

[0061] When it ******, as the wave number vector of the electron which tunnels an insulator layer is shown in drawing 4 , it is a perpendicular (thetac -10 degree) mostly, and it turns out that only the electron of the portion which gave the slash among the states of drawing 3 contributes to a tunnel current in a tunnel junction side. In addition, in the formula (2), s shows the thickness of a tunnel obstruction.
[0062] Here, the energy width of face of the portion which gave the slash is about 100 meV(s), and, in the case of l= 4nm, is Fermi energies EF. If about 5eV, it is Fermi energy EF. The energy interval of the portion which gave the slash in near is as large as about 1.0eV. That is, the s-electron in a magnetic-substance super-thin film is served just like the electron in an insulator layer in a tunnel junction, and does not contribute to a tunnel current.
[0063] In addition, although thickness of a super-thin film [magnetic substance] was set to 4nm, generally 5nm or less, then a tunnel current can be lessened here. In short, it is Fermi energy EF. What is necessary is for the energy interval of the portion which gave the slash in near to become large, and just to choose the thin thickness which an s-electron stops contributing to a tunnel current.
[0064] However, since sheet resistance will increase if only a magnetic-substance super-thin film is used for an electrode, as shown in drawing 5 , it is desirable to constitute a magnetic-substance electrode from a magnetic-substance super-thin film 8 and a conductive backup film 6 with sufficient thickness.
[0065] Although it is necessary to form the barrier film 7 which consists of an insulator between the magnetic-substance super-thin film 8 and the backup film 6 in order not to spoil the two-dimensional nature (2D EG) of the magnetic-substance super-thin film 8 in that case, the thickness of the barrier film 7 must fully be thinner than that of a tunnel insulator layer. In addition, five show Si substrate among drawing.
[0066] Moreover, it is also possible to use the cascade screen of the magnetic-substance super-thin film 8 for a magnetic-substance super-thin film, as shown not only in a monostromatic but in drawing 6 so that old explanation may show. Also in such a case, the thickness of the barrier film 7 needs to be thinner than that of a tunnel insulator layer enough.
[0067] As a magnetic-substance tunnel junction element 1, as shown, for example in drawing 7 , what has a Co/AlOx/Co tunnel junction is raised.
[0068] When this is explained according to a manufacturing process, it is SiO2 with a thickness of 5nm to the front face of the Si (100) substrate 10 first. A film 11 is formed by the oxidizing [thermally] method.
[0069] Next, SiO2 The Co film 12 with 50nm [in thickness as a lower electrode] and a width of face of 0.2mm is formed by the vacuum deposition method on a film 11. Here, the degree of vacuum in the case of vacuum deposition and substrate temperature are set as 1x10-8torr and 77K, respectively. Furthermore, the external magnetic field of 500Oe is impressed and, on the other hand, it is made equal [a magnetic easy shaft] to **.
[0070] Next, after forming aluminum film with a thickness of 1.2nm by the vacuum deposition method on the Co film 12, substrate temperature is returned to a room temperature, the A1 above-mentioned film is continuously oxidized by the glow discharge in the inside of oxygen atmosphere, and the tunnel insulator layer 13 which consists of Alx O is formed. The degree of vacuum in the case of vacuum deposition and substrate temperature are the same as a front.
[0071] Next, substrate temperature is again set as 77K, and the Co super-thin film 14 with 4nm [in thickness as an up electrode] and a width of face of 0.2nm is formed by the vacuum deposition method on the tunnel insulator layer 13. The degree of vacuum in the case of vacuum deposition is the same as a

front.
[0072] next, the front face of the Co [after returning substrate temperature to a room temperature] super-thin film 14 -- the inside of the oxygen atmosphere of 1x10-3torr -- **** during 1 minute -- the barrier film 15 is formed in the front face of the Co super-thin film 14 by things
[0073] Finally, the backup film 16 with a thickness of 50nm it is thin from Au is formed on the barrier film 15.
[0074] Thus, the magnetoresistance effect of the created magnetic-substance tunnel junction element was measured. This measurement was performed by impressing an external magnetic field in a tunnel junction side using the AC bridge.
[0075] The measurement result is shown in drawing 8 . The magnetic-reluctance property reflecting the magnetization curve is seen, and MR ratio is about 26%. Moreover, the absolute value of the bond resistance under a saturation magnetic field was about 20ohms.
[0076] The cross section of the magnetic-substance tunnel junction element which becomes drawing 9 from other Co/AlOx/Co tunnel junctions is shown. In addition, the same sign as drawing 7 is given to the magnetic-substance tunnel junction element of drawing 7 , and the corresponding portion, and detailed explanation is omitted.
[0077] A different point from the magnetic-substance tunnel junction element of drawing 7 uses the Co super-thin film 14 not only for an up electrode but for a lower electrode, and is to have formed the backup film 17 and the barrier film 18 also in the lower electrode side further. Cu film with a thickness of 50nm is used as a backup film 17. Thus, a tunnel junction is formed also in a lower electrode side.
[0078] Cu film which is the backup film 17 sets substrate temperature to 77K, and forms it by the vacuum deposition method, and the barrier film 18 returns substrate temperature to a room temperature after formation of the backup film 17, and forms it by exposing the backup film 17 into the oxygen atmosphere of 1x10-3torr for 1 minute. The formation method of other films is the same as the case of the element of drawing 7 .
[0079] Although the bond resistance under a saturation magnetic field was 22ohms when the magnetoresistance effect of this element was measured by the same method as the case of the magnetic-substance tunnel junction element of drawing 7 , MR ratio was increasing to 35%.
[0080] Moreover, in the magnetic-substance tunnel junction element of drawing 7 , the magnetic-substance tunnel junction element which transposed the Co super-thin film with a thickness of 4nm which is an up electrode to Co film with a thickness of 50nm was formed as an example of comparison. The formation applies to it of the magnetic-substance tunnel junction element of drawing 7 correspondingly.
[0081] Although the bond resistance under a saturation magnetic field was 18ohms when the magnetoresistance effect of this element was measured by the same method as the magnetic-substance tunnel junction element of drawing 7 , MR ratio was 15% and was smaller than drawing 7 and MR ratio of the element of drawing 8 .
[0082] (2nd operation gestalt) The magnetic memory cell which starts the 2nd operation gestalt of this invention at drawing 10 is shown. In addition, the same sign as drawing 1 is given to the magnetic memory cell of drawing 1 , and the corresponding portion, and detailed explanation is omitted.
[0083] This operation gestalt is the example which used the hot electron transistor as a GMR element. A hot electron transistor is a GMR element which shows bigger MR ratio than a magnetic-substance tunnel junction element. MR ratio of a hot electron transistor exceeds 200%. Therefore, it becomes easier to read the information on a memory cell correctly, and it can lessen a read error.
[0084] However, the current gain of a hot electron transistor will be small, and, in the case of the grounded base, a collector current will decrease by 1 or more figures from an emitter current.
[0085] For this reason, like the case of a magnetic-substance tunnel junction element, in order to carry out high-speed operation about ns, as shown in drawing 10 </A>, connecting with the gate of MOS transistor 2 is desirable [a hot electron transistor 9 (collector)].
[0086] by the way, the thing for which an emitter current is enlarged for high-speed operation since the current gain in the grounded base is presumed to be at most about 0.1 -- it is desirable

[0087] In order to pass a big emitter current, the Schottky pouring type hot electron transistor of drawing 27 is more desirable than the tunnel pouring type hot electron transistor of drawing 26 .
[0088] Since it forms on the same substrate as a MOS transistor when forming the hot electron transistor of drawing 26 , Si will be used for the material of a collector layer. Although Si layer is sufficient as a collector layer, it is desirable that it is the semiconductor layer with which it is satisfied of the following conditions as an emitter layer. That is, a band gap is large and a low semiconductor layer has desirable membrane formation temperature.
[0089] The reason with desirable membrane formation temperature being low is that there is a possibility that the property of the magnetic cascade screen which is a base layer may deteriorate when membrane formation temperature is high in order to form an emitter layer after a base layer.
[0090] Moreover, the reason with desirable a band gap being large is that it can reduce quantum mechanics-reflection of the base / collector interface by using the high electron of energy.
[0091] As a semiconductor layer which fulfills such two conditions, the n type titanic-acid stolon CHUUMU (STO) layer (Nb dope n type STO layer) by which Nb was doped is most suitable.
[0092] The dependency of the collector to base voltage (VEB) of the emitter current (IE) at the time of using a Nb dope n type STO layer for drawing 11 as an emitter layer is shown.
[0093] impressing about [0.9V] voltage between the collector bases from drawing -- 103 -- A/cm2 It turns out that the emitter current of a grade flows. In this case, supposing a current gain is 0.1, a read time is set to 0.1ns, and even if a current gain is 0.01, it will turn into 1ns of read times.
[0094] (3rd operation gestalt) The magnetic head which starts the 3rd operation gestalt of this invention at drawing 12 is shown. In addition, the same sign as drawing 1 is given to the magnetic memory cell of drawing 1 , and the corresponding portion, and detailed explanation is omitted.
[0095] The magnetic head of this operation gestalt has composition which removed bit line BL, word line WL, and the magnetization means from the magnetic memory cell of drawing 1 .
[0096] In case the magnetic reluctance of the magnetic-substance tunnel junction element 1 scans a magnetic-recording medium top, it can change, and it can read the information written in the magnetic-recording medium by detecting the voltage change corresponding to this with a sense amplifier.
[0097] High-speed read-out also of the magnetic head of this operation gestalt becomes possible for the same reason as the case of the magnetic memory of the 1st operation gestalt.
[0098] (4th operation gestalt) The magnetic head which starts the 4th operation gestalt of this invention at drawing 13 is shown. In addition, the same sign as drawing 10 is given to the magnetic memory cell of drawing 10 , and the corresponding portion, and detailed explanation is omitted.
[0099] The magnetic head of this operation gestalt has composition which removed bit line BL, word line WL, and the magnetization means from the magnetic memory cell of drawing 10 .
[0100] In case the magnetic reluctance of a hot electron transistor 9 scans a magnetic-recording medium top, it can change, and it can read the information written in the magnetic-recording medium by detecting the voltage change corresponding to this with a sense amplifier.
[0101] High-speed read-out also of the magnetic head of this operation gestalt becomes possible for the same reason as the case of the magnetic memory of the 2nd operation gestalt. Moreover, since bigger MR ratio than a magnetic-substance tunnel junction element is obtained, a read error can be lessened.
[0102] According to research of this invention person, in (the 5th operation gestalt) and time, it found out that MR ratio increased as a magnetic-substance electrode by using the cascade screen of a magnetic-substance super-thin film several nm or less or a magnetic-substance super-thin film, and barrier films, such as a dissimilar-metal film.
[0103] Although the electron of strong d band of localization nature and s band near a free electron lives together in ferromagnetic metals, such as Fe, Co, and nickel, as explained previously, the tunnel current is mainly borne by the s-electron.
[0104] It is thought that the cause that MR ratio of a magnetic-substance tunnel junction falls remarkably in a practical use voltage field is because electronic spin is reversed, i.e., an electronic spin flip phenomenon. Therefore, in order to obtain the tunnel junction which shows big MR ratio in a practical use voltage field, it is required to suppress this spin flip phenomenon by a certain method.

[0105] Here, although the s-electron in a magnetic-substance super-thin film was quantized by the dispersed energy level in the tunnel junction as shown in drawing 3 , this invention person found out that the energy levels differed by the rise spin electron and the down spin electron for the first time this time.

[0106] For example, when a Fe super-thin film with a thickness of 1nm is used as a magnetic-substance super-thin film, the difference of the energy level of a rise spin electron and a down spin electron serves as a very big value of about 1eV.
[0107] Thus, in the magnetic-substance tunnel junction using the electrode which consists of a magnetic-substance super-thin film, in order to have to receive inelastic scattering in which about 1eV energy participated in order for a tunnel electron to carry out spin reversal, the probability that a spin flip phenomenon will happen becomes remarkably low.
[0108] It becomes possible to realize the magnetic-substance tunnel junction element which shows big MR ratio which exceeds 10% in a practical use voltage field by such reduction-ization of the probability of occurrence of a spin flip phenomenon.
[0109] In addition, since sheet resistance will increase if only a magnetic-substance super-thin film is used for an electrode, as shown in drawing 5 , it is desirable to constitute a magnetic-substance electrode from a magnetic-substance super-thin film 8 and a conductive backup film 6 with sufficient thickness.
[0110] As previously explained also in this case, in order not to spoil the two-dimensional nature (2D EG) of the magnetic-substance super-thin film 8, it is good to form the thin barrier film 7. Moreover, as shown in drawing 6 , it is also possible to use the cascade screen of the magnetic-substance super-thin film 8, and it is good to form the thin barrier film 7 also in that case.
[0111] Hereafter, the GMR element (tunnel pouring type hot electron transistor) of this operation form is explained concretely.
[0112] The collector 21 (semiconductor region) which consists of n type Si as this GMR element is shown in drawing 14 , The base 22 which consists of a cascade screen of Au film (thickness : 1.5nm) / Fe film (thickness : 1.5nm) / aluminum film (thickness : 10nm), AlOx It has composition which the backup film (un-illustrating) which consists of an Au film (thickness : 100nm) joined to the emitter 23 (magnetic-substance electrode) which consists of a cascade screen of a film (tunnel insulator layer) / Fe film one by one.
[0113] When MR ratio of this GMR element was investigated, it turns out that it depends for the size on the thickness of Fe film of an emitter 23 greatly. this invention person created three kinds of GMR elements (d= 0.8nm, 1nm, 2nm) from which the thickness d of Fe film of an emitter 23 differs, and investigated the emitter voltage dependency of the MR ratio.
[0114] The result is shown in drawing 15 . Measurement was performed in the environment of temperature 77K. Moreover, as shown in drawing 14 , negative emitter voltage was impressed to the emitter 23 to the collector 21. Drawing 15 shows that MR ratio is so large that the thickness d of Fe film of an emitter 23 is thin also on the same emitter voltage.
[0115] Moreover, this invention person investigated the thickness dependency of Fe film of the emitter 23 of MR ratio. The result is shown in drawing 16 . In addition, emitter voltage is 1V. Moreover, the degree of spin polarization for which it asked from MR ratio using the conduction parameter in the base reported until now is also shown in drawing.
[0116] From drawing 16 , at least 5nm will increase MR ratio rapidly, if it goes down 2nm, although MR ratio is obtained, for example, emitter (Fe) thickness exceeds double precision (100%) in 0.8nm, and MR ratio falls rapidly by 0.6nm, and if 0.5nm is gone down, MR ratio will no longer be obtained.
[0117] Moreover, it turns out that the degree of spin polarization will become under 0.05 (5%) from drawing if 3nm is exceeded, the degree of spin polarization will increase rapidly on the other hand if 2nm is gone down, for example, 0.4 (40%) is exceeded in 0.8nm.
[0118] 0. The result in 8 nm is almost equal to the degree of spin polarization of the tunnel electron measured in the several mV low-battery field reported until now. That is, if thickness of Fe film of an emitter 23 is set to 1nm or less, even if it impresses about [1V] high voltage, since the tunnel ring of the electron is carried out without hardly carrying out a spin flip, it can pass the electron current which

carried out spin polarization.
[0119] Even if emitter (Fe) thickness has 0.5nm or more desirable 5nm or less, and it impresses about [1V] high voltage, i.e., the voltage of a practical use voltage field, to an emitter 23 in this way from the above result by [with 0.6nm or more more desirable 2nm or less] thin-film-izing Fe film of an emitter 23 according to this operation gestalt, the GMR element which shows MR ratio big enough can be realized.
[0120] (6th operation gestalt) Drawing 17 is the cross section showing the magnetic-substance tunnel junction element concerning the 6th operation gestalt of this invention.
[0121] When this is explained according to a manufacturing process, it is SiO2 with a thickness of 5nm on the Si (100) substrate 31 (semiconductor region) first. A film 32 is formed. Next, substrate temperature is set as 77K and it is SiO2. The backup film 33 which consists of Cu is formed on a film 32. Then, it returns to a room temperature and the barrier film 34 is formed in the front face of the backup film 33 by oxidization for [in the inside of the oxygen atmosphere of 1x110-6Torr] 1 minute.
[0122] Next, the Co super-thin film 35 with a thickness [as a lower electrode] of 0.8nm is formed with vacuum deposition on the barrier film 34. At this time, the external magnetic field of 500e is impressed and, on the other hand, it is made equal [a magnetic easy shaft] to **. Moreover, the degree of vacuum in the case of vacuum deposition and substrate temperature are 1x10-8torr and 77K, respectively.
[0123] Next, after forming aluminum film (un-illustrating) with a thickness of 1.2nm on the Cu super-thin film 35, substrate temperature is returned to a room temperature, the A1 above-mentioned film is continuously oxidized by the glow discharge in the inside of oxygen atmosphere, and the tunnel insulator layer 36 which consists of Alx O is formed. The degree of vacuum in the case of vacuum deposition and substrate temperature are the same as a front.
[0124] Next, substrate temperature is again set as 77K, and the Co super-thin film 37 with a thickness [as an up electrode] of 1nm is formed by the vacuum deposition method on the tunnel insulator layer 36. The degree of vacuum in the case of vacuum deposition and substrate temperature are the same as a front.
[0125] next, the front face of the Co [after returning substrate temperature to a room temperature] super-thin film 37 -- the inside of the oxygen atmosphere of 1x10-6torr -- **** during 1 minute -- the barrier film 38 is formed in the front face of the Co super-thin film 37 by things
[0126] Finally, the backup film 39 with a thickness of 50nm it is thin from Au is formed on the barrier film 38.
[0127] Thus, the magnetoresistance effect of the created magnetic-substance tunnel junction element was measured. This measurement was performed by impressing an external magnetic field in a tunnel junction side using the AC bridge.
[0128] Consequently, the magnetic-reluctance property reflecting the magnetization curve is seen, and MR ratio is about 30%. Moreover, the absolute value of the bond resistance under a saturation magnetic field was about 20ohms.
[0129] Moreover, what transposed the up electrode and the lower electrodes 35 and 37 of a magnetic-substance tunnel junction element of this operation gestalt to Co film with a thickness of 50nm was formed as an example of comparison. The formation applies to it of this operation gestalt correspondingly.
[0130] Although the bond resistance under a saturation magnetic field was 18ohms when the same method estimated the magnetoresistance effect of the example of comparison, MR ratio was 5% and was far smaller than MR ratio of the magnetic-substance tunnel junction element of this operation gestalt.
[0131] (7th operation gestalt) Drawing 18 is the cross section showing the magnetic-substance element concerning the 7th operation gestalt of this invention.
[0132] Among drawing, 41 show the semiconductor substrate (semiconductor region), the 1st magnetic-substance electrode 42 which consists of a magnetic-substance super-thin film is formed in the end side of this semiconductor substrate 41, and the 2nd magnetic-substance electrode 43 which consists of a magnetic-substance super-thin film is formed in the other end side. As a semiconductor substrate, a Fe super-thin film is used, for example as Si substrate and a magnetic-substance super-thin film, for

example.
[0133] The semiconductor substrate 41 and the 1st magnetic-substance electrode 42 form the Schottky barrier, and the semiconductor substrate 41 and the 2nd magnetic-substance electrode 43 form the Schottky barrier similarly. Moreover, the thickness of the 1st and 2nd magnetic-substance electrodes 42 and 43 is 0.5nm or more (0.6 or more [Preferably]) 5nm or less (preferably 2nm or less).
[0134] Thus, according to the constituted magnetic-substance element, if negative voltage is impressed to the 1st magnetic-substance electrode 42 to the 2nd magnetic-substance electrode 43, an electron can be injected into the semiconductor substrate 41 through the Schottky barrier from the 1st magnetic-substance electrode 42, without causing a spin flip phenomenon.
[0135] Therefore, according to this operation gestalt, the electron current Ie which carried out spin polarization toward the 2nd magnetic-substance electrode 43 from the 1st magnetic-substance electrode 42 can be passed now in the semiconductor substrate 41.
[0136] The modification of this operation gestalt is shown in drawing 19 . This shows the structure in the case of passing the electron current Ie in the vertical direction. Moreover, with this operation gestalt, although the monolayer of a super-thin film [magnetic substance] was used as magnetic-substance electrodes 42 and 43, you may use the cascade screen of a magnetic-substance super-thin film and the barrier film to an electron, for example. As a barrier film, if it works as barrier, there is no limit in the membrane type, for example, an insulator layer, a semiconductor film, a semimetal film, and a dissimilar-metal film can be used.
[0137] (Operation gestalt of the octavus) Drawing 20 is the cross section showing the magnetic-substance element concerning the operation gestalt of the octavus of this invention. In addition, the same sign as drawing 18 is given to the magnetic-substance element of drawing 18 , and the corresponding portion, and detailed explanation is omitted (the same about other following operation gestalten).
[0138] This operation gestalt forms the gate electrode 44 in the front face of the semiconductor substrate 41 between the 1st magnetic-substance electrode (source electrode) 42 and the 2nd magnetic-substance electrode (drain electrode) 43, and is to have constituted FET. The semiconductor substrate 41 and the gate electrode 44 form the Schottky barrier.
[0139] It compares, when controlling the electron current in which the rise spin electron and the down spin electron were intermingled, since the electron current Ie which carried out spin polarization is controllable by the gate voltage according to this operation gestalt, and it is a mutual conductance gm. Big FET can be realized now.
[0140] In addition, a gate insulator layer may be formed on the semiconductor substrate 41, and the 1st magnetic-substance electrode (source electrode) 42, the 2nd magnetic-substance electrode (drain electrode) 43, and the gate electrode 44 may be formed on it.
[0141] (9th operation gestalt) Drawing 21 is the cross section showing the magnetic-substance element concerning the 9th operation gestalt of this invention.
[0142] This operation gestalt is the example which applied this invention to Light Emitting Diode, pours in the electron current Ie which carried out spin polarization to the semiconductor substrate 41 of undoping from the 1st magnetic-substance electrode 42, and pours in the hole current Ih which carried out spin polarization to the semiconductor substrate 41 from the 2nd magnetic-substance electrode 43. Thereby, the reunion of an electron and an electron hole happens and luminescence arises.
[0143] Since reunion can be caused by the electron current Ie and the hole current Ih which carried out spin polarization according to this operation gestalt, compared with the case where reunion is caused, voltage required for luminescence is low and can be managed with the electron current and the hole current in which the rise spin electron and the down spin electron were intermingled.
[0144] In addition, the semiconductor layer of undoping of 45 is shown among drawing. Recombination velocity is controllable by the applied voltage of this semiconductor layer 45.
[0145] (10th operation gestalt) Drawing 22 is the cross section showing the magnetic-substance element concerning the 10th operation gestalt of this invention. It is the example in which this operation gestalt also applied this invention to Light Emitting Diode.
[0146] The point that this operation gestalt differs from the 9th operation gestalt is to have constituted

Light Emitting Diode using the impurity dope semiconductor. The 1st magnetic-substance electrode 42 is joined to the n-type-semiconductor substrate 41 through p type semiconductor layer 45p. Moreover, p type semiconductor layer 45p is used instead of the semiconductor layer 45 of undoping. The same effect as the 9th operation gestalt is acquired also with this operation gestalt.
[0147] (11th operation gestalt) Drawing 23 is the cross section showing the magnetic-substance element concerning the 11th operation gestalt of this invention. This operation gestalt is the example which applied this invention to laser. A p type semiconductor layer (semiconductor region) and 46i show the i-type-semiconductor layer (semiconductor region), and inside of drawing and 46p shows 46n (semiconductor region) of n-type-semiconductor layers.
[0148] Since the inverted population can be formed by the electron current Ie and the hole current Ip which carried out spin polarization according to this operation gestalt, compared with the case where the inverted population is formed, voltage (threshold voltage) required for laser oscillation becomes low by the electron current and the hole current in which the rise spin electron and the down spin electron were intermingled.
[0149] (12th operation gestalt) Drawing 24 is the cross section showing the magnetic-substance element concerning the 12th operation gestalt of this invention. This operation gestalt is the example which applied this invention to the spin transistor. 47 show the tunnel insulator layer among drawing, and 48 shows the paramagnetic-material layer (magnetic-substance field). The paramagnetic-material layer 48 is grounded.
[0150] Since the electron current Ie which carried out spin polarization from the 1st magnetic-substance electrode 42 can be injected into the paramagnetic-material layer 48 according to this operation gestalt, compared with the case where the electron current in which the rise spin electron and the down spin electron were intermingled is poured in, a big voltage difference can be generated by between the 2nd magnetic-substance electrode 43 and the paramagnetic-material layers 48.
[0151] (13th operation gestalt) Drawing 25 is the cross section showing the magnetic-substance element concerning the 13th operation gestalt of this invention. This operation gestalt is the example which applied this invention to the hot electron transistor. 49 show the ferromagnetic layer among drawing and 50 shows the semiconductor layer (semiconductor region).
[0152] Since the electron current Ie which carried out spin polarization can be injected into the semiconductor layer 50 through the tunnel insulator layer 47 from the 1st magnetic-substance electrode 42 according to this operation gestalt, bigger MR ratio is obtained compared with the case where the electron current in which the rise spin electron and the down spin electron were intermingled is poured in.

[Translation done.]

EFFECT OF THE INVENTION

[Effect of the Invention] Since CR time constant leading to a time delay can be made small according to this invention (claims 1-7) as explained in full detail above, a magnetic device with a quick read-out speed can be realized.

[0154] Moreover, according to this invention (claims 8-12), the magnetic-substance element which can suppress property degradation resulting from the spin flip phenomenon of the electron in a practical use voltage field can be realized now by using a magnetic-substance super-thin film as a magnetic-substance electrode.

[Translation done.]

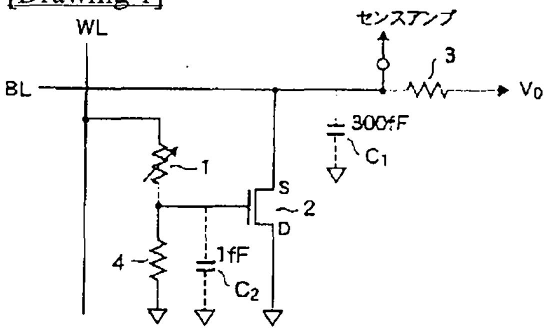
CLAIMS

[Claim(s)]
[Claim 1] The magnetic device which is connected to the gate of an MOS transistor and this MOS transistor, possesses the GMR element as a magnetic-head main part, and is characterized by the bird clapper.
[Claim 2] The magnetic device to which the memory cell which is connected to the gate of an MOS transistor and this MOS transistor, and consists of a GMR element as a memory cell main part is characterized by carrying out array formation at the shape of a matrix.
[Claim 3] The magnetic device according to claim 2 characterized by having further the magnetization control means which control the direction of magnetization of the aforementioned GMR element.
[Claim 4] It is the magnetic device according to claim 1 or 2 which it connects with the source of a constant voltage through the aforementioned GMR element, and the gate of the aforementioned MOS transistor is grounded through the 1st resistance, and the source of the aforementioned MOS transistor is connected to the 2nd resistance of low resistance in series rather than the 1st aforementioned resistance, and is characterized by grounding the drain of the aforementioned MOS transistor.
[Claim 5] The aforementioned GMR element is a magnetic device according to claim 1 or 2 characterized by being a magnetic tunnel junction element or a base layer being the hot electron transistor formed by the magnetic cascade screen.
[Claim 6] The electrode of the aforementioned magnetic tunnel junction element is a magnetic device according to claim 5 characterized by being formed by the cascade screen of a magnetic film or a magnetic film, and an insulator layer.
[Claim 7] The emitter layer of the aforementioned hot electron transistor is a magnetic device according to claim 5 characterized by being formed by the strontium-titanate film by which Nb was doped.
[Claim 8] The magnetic-substance element which possesses the poured in field which consists of the semiconductor region or paramagnetism metal field where the electron current which carried out spin polarization is poured in through the potential barrier over an electron, and is characterized by the bird clapper from the magnetic-substance electrode containing a magnetic-substance super-thin film, and this magnetic-substance electrode.
[Claim 9] The thickness of a super-thin film [magnetic substance / aforementioned] is a magnetic-substance element according to claim 8 characterized by 0.5nm or more being 5nm or less.
[Claim 10] The magnetic-substance element according to claim 8 characterized by using a tunnel junction, the Schottky barrier, or MIS junction as the aforementioned potential barrier when the aforementioned poured in field is a semiconductor region.
[Claim 11] The magnetic-substance element according to claim 8 characterized by using a tunnel junction as the aforementioned potential barrier when the aforementioned poured in field is a paramagnetism metal field.
[Claim 12] The aforementioned magnetic-substance electrode is a magnetic-substance element according to claim 8 characterized by the bird clapper from the cascade screen of the aforementioned magnetic-substance super-thin film and the barrier film to an electron.

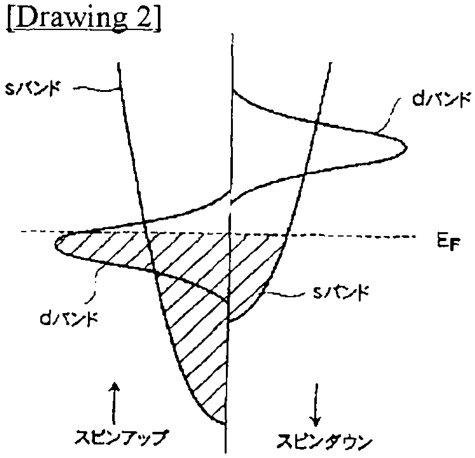
[Translation done.]

DRAWINGS

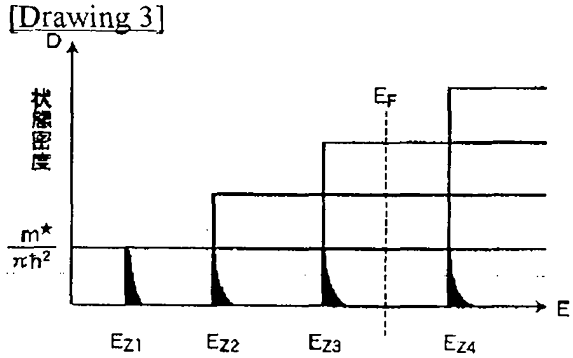
[Drawing 1]



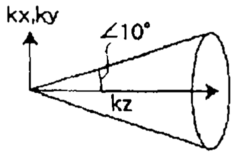
[Drawing 2]



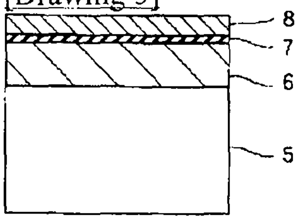
[Drawing 3]



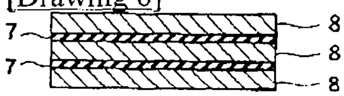
[Drawing 4]



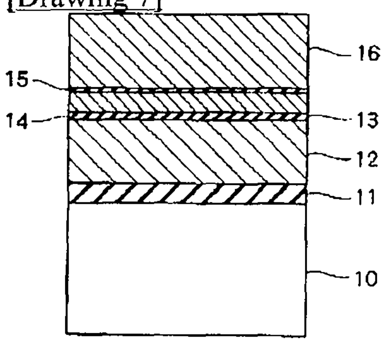
[Drawing 5]



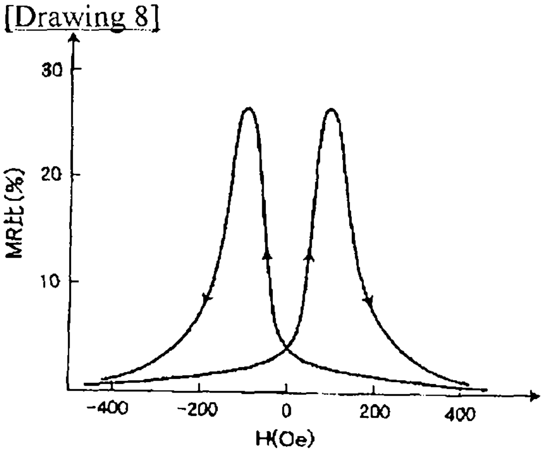
[Drawing 6]



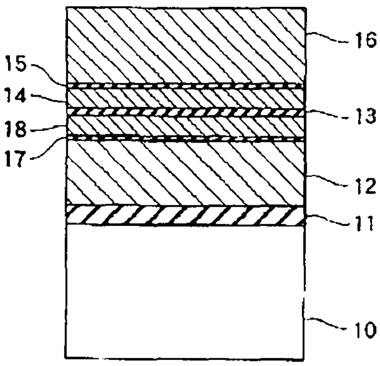
[Drawing 7]



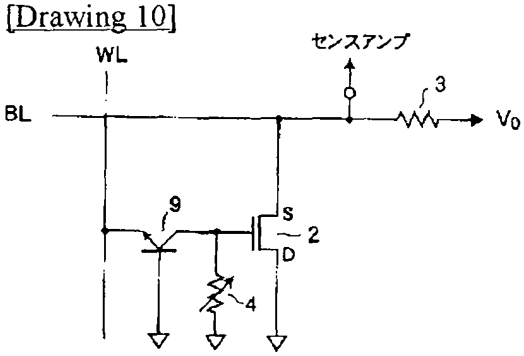
[Drawing 8]



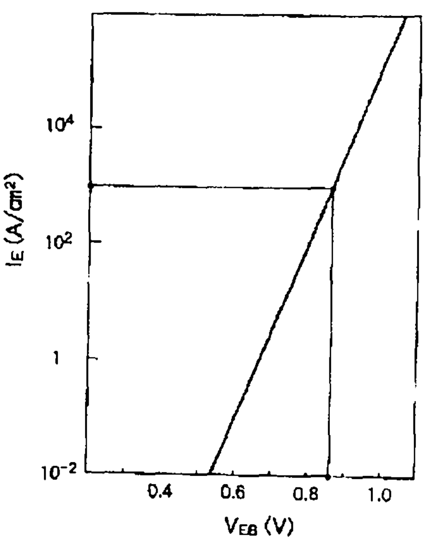
[Drawing 9]



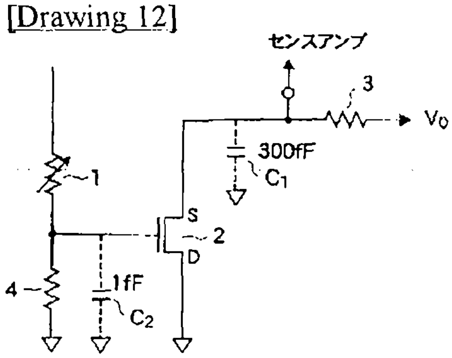
[Drawing 10]



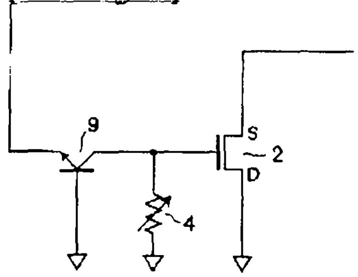
[Drawing 11]



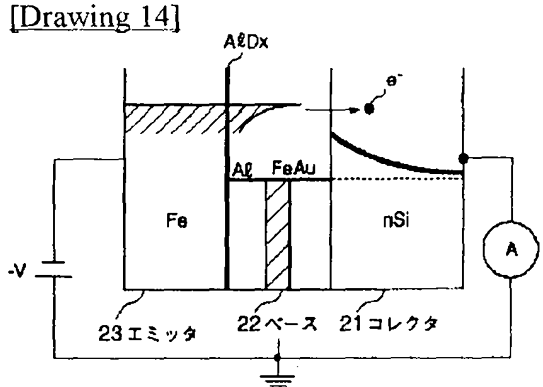
[Drawing 12]



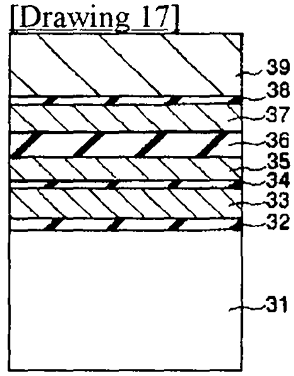
[Drawing 13]



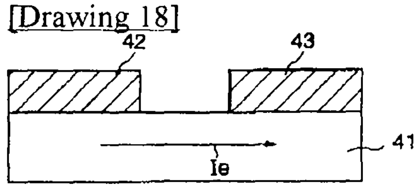
[Drawing 14]



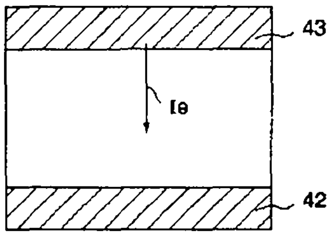
[Drawing 17]



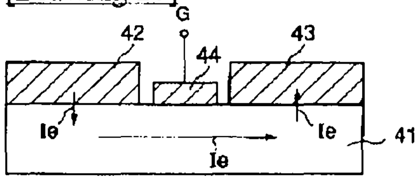
[Drawing 18]



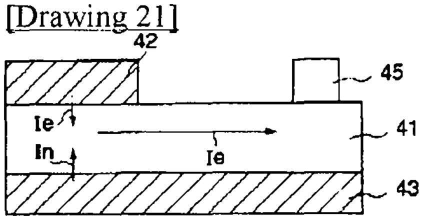
[Drawing 19]



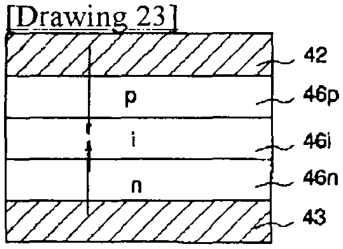
[Drawing 20]



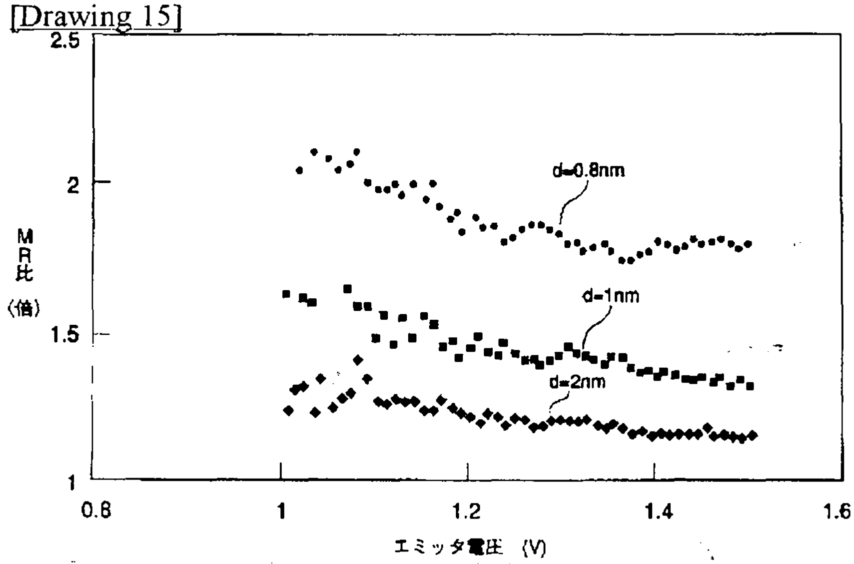
[Drawing 21]



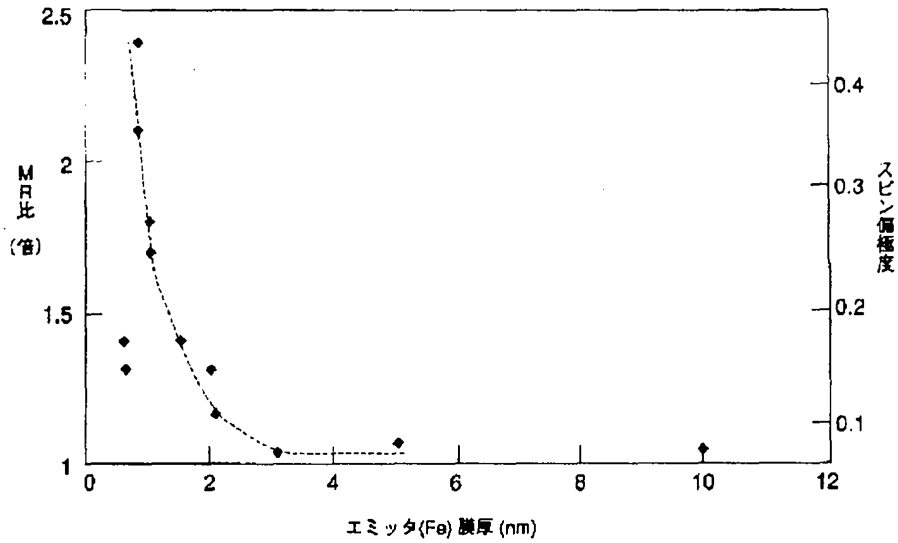
[Drawing 23]



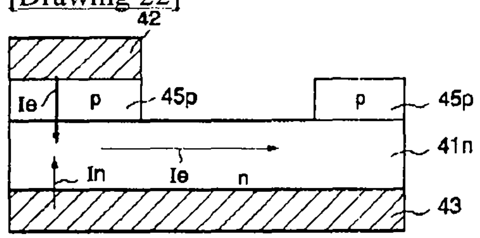
[Drawing 15]



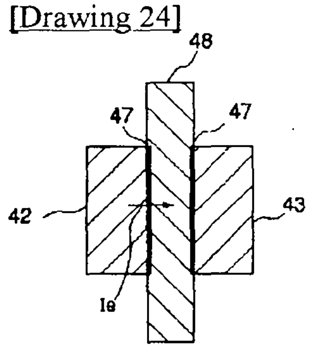
[Drawing 16]



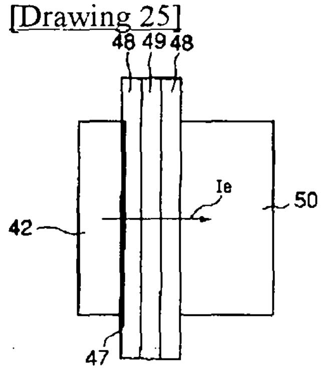
[Drawing 22]



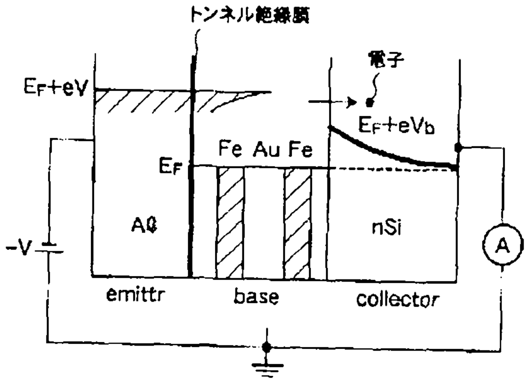
[Drawing 24]



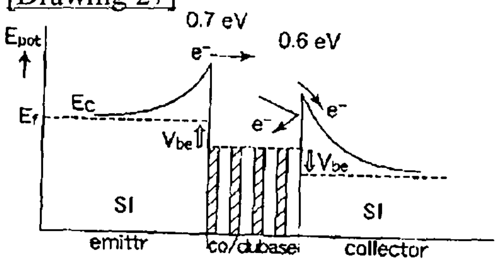
[Drawing 25]



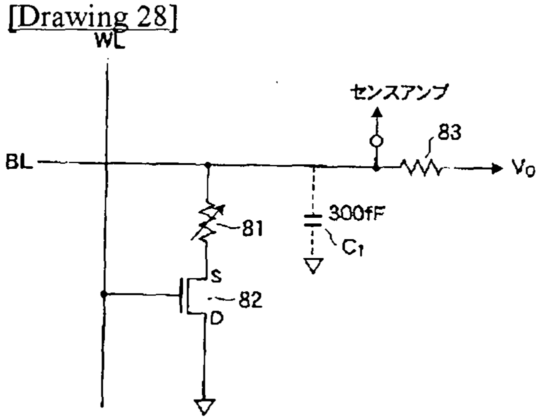
[Drawing 26]



[Drawing 27]



[Drawing 28]



[Translation done.]